# A GENERAL REPORT ON THE PHYSIOGRAPHY OF MARYLAND

## A DISSERTATION

PRESENTED TO THE PRESIDENT AND FACULTY OF THE JOHNS HOPKINS UNIVERSITY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

BY

CLEVELAND ABBE, Jr.

BALTIMORE, MD.
MAY, 1898.

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## Physiographic Processes.

### INTRODUCTION.

From the earliest times men have observed more or less closely the various phenomena which nature presents, and have sought to find an explanation for them. Among the most interesting of these phenomena have been those which bear on the development of the surface features of the earth or its topography. Impressed by the size and grandeur of the mountains, their jagged crests and scarred sides, early students of geographical features were prone to ascribe their origin to great convulsions of the earth's crust, earthquakes and volcanic eruptions.

One generation after another comes and goes, yet the mountains continue to rear their heads to the same heights, the rivers to run down the mountain sides in the same courses and follow the same valleys to the sea. So men came to look upon the mountains as permanent after they were upheaved, and adopted them as symbols of eternity and unchangeableness. How often to-day, even, do we hear expressions such as "the everlasting hills," and "firm as a rock." With such conceptions concerning the origin of mountains and their duration went the related ideas that the rivers found valleys ready made for them in the shape of cracks and chasms in the earth, formed during the birth of the mountain ranges. Those who held these views thus saw no relations whatever between the mountains and the rains which fell upon them, between the rivers and the shaping of the valleys which held them. They believed the mountains existed first and that the rains, snows, glaciers and rivers came afterwards.

Other men recognized in the waters flowing through the valleys a powerful agent by means of which the gorges, canyons, and broader valleys had been carved out. This carving, however, they believed to have been done in some long past period, when a great volume of water swept down the river courses, tearing away rocks and trees and fashioning the valley; or they held that all the lands of the earth were at one time submerged by the ocean, and that great currents, flowing in the seas of that period, carved out the river valleys which we see to-day. Those who held such views are now called the Catastrophists, because they appealed to great convulsions, catastrophes and cataclysms to explain the various geological and geographical phenomena which they saw about them.

Upholders of the cataclysmic theories concerning the origin of the earth's features were numerous and even in the majority as late as the beginning of the present century, yet a few individual thinkers had centuries before held different and what are now believed to be truer ideas concerning geological phenomena. Among the early forerunners of the present school were Aristotle and Strabo. Aristotle opposed the catastrophic teachings, saying that "the changes of the earth are so slow in comparison to the duration of our lives, that they are overlooked."[1] Strabo also maintained that the features of the land and sea were to be explained by the operation of natural processes during past ages.

Thus early were foreshadowed the conclusions which Hutton pronounced as the result of his studies in the fields and on the shores of Great Britain. These conclusions are briefly summarized in the following statement given by Playfair:[2] "Amid all the revolutions of the globe the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents, have been changed in all their parts; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same."

[1] See Lyell, "Principles," 1873. p. 21, quoted from "De Die Natura."
[2] Playfair, "Illustrations of the Huttonian Theory." p. 374.

In this passage is the key to the principles which have guided the modern study of geology and geography. Since the year 1785, in which Hutton published his "Preliminary Sketch of the Theory of the Earth," the student of the Earth Sciences has been guided more and more by the principle that the Past is to be interpreted in the light of the Present.

To-day we recognize that the greater number of the valleys have been carved in the landmasses by the everlasting and continuous action of the weather in breaking up the rocks and of the rivers in carrying these broken rocks away. We do not regard the earth's features as the products of convulsions or catastrophes such as deluges or holocausts, but as resulting from the interaction of two sets of agencies, slow in performance but powerful and all-pervading. One set of agents continually strive to build up the land above the seas, and these we call agents of construction; the other set of agents as constantly and persistently strive to tear down or destroy the work performed by the first class, and to this set we give the name of destructional agents or agents of denudation. We have, then, to consider two great classes, the agents and processes of construction and the agents and processes of destruction or denudation.

### PROCESSES OF DENUDATION.[1]

The agents of denudation are all the time actively carrying on their work about us. Indeed, most of them are perfectly familiar to us and frequently attract our attention, but we rarely or never stop to think what they mean, what relation they bear to the surface forms of the earth, or even what influences they exert upon us. It will be profitable then to consider briefly these agents and their methods of work.

For convenience of treatment, the different agents and their proper processes may be grouped into three general classes, viz. *Atmospheric*, or those agents and processes which are peculiar to the atmosphere as we commonly regard it; *Aqueous* or hydrous, or the action of

[1] The main facts and principles of rock-weathering as explained in the sequel, are taken from G. P. Merrill's "Rocks, Rock-Weathering and Soils." 1897. pp. 172, et seq.

moisture and water after it has left the atmosphere; *Organic* agents and processes, whose effectiveness is due to the direct or indirect intervention of members of the Animal or Vegetable kingdoms.

### *Atmospheric Processes.*

The direct chemical activity of the atmosphere in breaking down the rocks is not very great. The atmosphere contains, in addition to its essential constituents nitrogen (4/5) and oxygen (1/5), very appreciable quantities of a number of gases such as carbonic acid gas, nitric acid gas, and ammonia, which, when in combination or aided by moisture, are very effective agents of rock disintegration and decay, but when in the dry state as parts of the atmosphere, possess but little chemical power. It is therefore the water vapor in the atmosphere which plays the most important part in the atmospheric processes. This will be treated of separately and need not be further noticed here since it becomes most effective after collecting as rain.

The mechanical processes of the atmosphere are of more direct influence. Districts which are subject to an extreme daily range in temperature, as the peaks of high mountain ranges, most tropical countries and many continental interiors, present many striking illustrations of the way in which rapid alternations of expansion and contraction cause rocks to break up. After a long day, during which the sun pours down its heat upon the exposed ledges and raises them at times to temperatures far exceeding 100° F., there succeeds a clear night during which rapid radiation and cooling takes place. Thus the rocks may undergo variations in temperature amounting oftentimes to a range of more than 75° F. within twenty-four hours. Such rapid and considerable expansion and contraction as this change in temperature involves cause the exposed rocks to crack or "scale." In this way large fragments of slight thickness may be broken off. Livingstone reports that in parts of Africa angular masses of rocks weighing 200 pounds and more are thus split from the parent ledge. Many instances of this method of rock breaking are reported from the high mountains of western America, and throughout the northern tier of states where the conditions are favorable.

Another mode of rock disintegration results from the different amounts of expansion exhibited by the various mineralogical constituents of a rock. When a piece of granite, for example, is raised to a moderate temperature, say summer heat or 78° F., the feldspar, hornblende, mica and other minerals composing it expand. The amount of expansion differs so greatly in different minerals that an uneven distribution of strains is produced throughout the mass which tends to loosen the interlocking grains. The continued annual and daily expansion and contraction of the rocks may cause them in time to break down into sand and gravel.

An effective agent of denudation at certain points in Maryland is found in the atmosphere in motion or the wind. As the wind blows over the surface of the ground or across bare exposed mountain peaks it catches up the lighter particles of soil and rock debris and whirling them up into the air, may project them with considerable force against opposing cliffs or other immovable objects. The effect upon both the rock particles and the objects hit is similar to that of a sand blast. Various cliffs in California, Arizona and other portions of the West have been carved into fantastic shapes by this natural sand blast. In South America the upper portions of certain cliffs have been so undercut that the remnants appear as huge boulders perched upon the ledges by some mighty transporting agent. On sandy shores, such as Cape Cod, or, in the wastes of the Sahara, the flying sands have been found to polish and plane down pebbles too large to be moved by the wind. Sometimes, as in the deserts of South Africa, the pebbles show longitudinal scratches and grooves worn in them by the flying sands.

Besides thus aiding in wearing down the resistant rocks, the wind also modifies the earth's surface by transporting sand and soil from one point to another. In this respect the destructional and the constructional effects of the wind merge into each other. The destructional process was illustrated in an interesting manner last year when the Loch Raven reservoir was being cleaned out. The cleaning necessitated the drawing off of a considerable portion of the water, as the result of which a broad shoal of mud and sand which had collected near the upper end of the Loch Raven gorge was laid bare. This flat being exposed to the hot September sun and brisk winds became thoroughly dried, until the grains of sand no longer cohered. The prevailing west wind "drawing" into the narrow chasm caught up the dry sand, and, driving it out of the channel, drifted it upon the road at the curve, covering it to a depth of nearly a foot. In a somewhat similar manner great quantities of sand are annually carried from the long sandy beaches of our Atlantic coast line and either driven out to the sea or into the lagoons between the beaches and the mainland. In arid regions the wind may become a very important agent in the removal of rock debris.

Thus the atmosphere is seen to furnish chemical agents for rock solution and decay, to aid in the mechanical disintegration of the rocks through its changes in temperature and to carve or transport the finely ground products of their disintegration.

*Aqueous Processes.*

Pure water falling upon the bare rocks of mountains or wind-swept ledges on the lowlands would have but slight effect chemically in breaking down the rocks into rock debris and into the finer particles which make up the soils of the earth's surface.

Atmospheric water commonly contains in solution in small quantities nitric acid, ammonia, and carbonic acid as well as other less important substances, so that the rain upon reaching the earth is a powerful chemical agent, which can produce important changes in the rocks of the earth's crust. Rocks containing iron-bearing minerals, such as iron-pyrites, the amphiboles, pyroxenes, etc., also suffer considerable disintegration as a result of oxidation or rusting out of those minerals. The oxidation also involves at times an increased size or swelling of the altered mineral, so that physical strains and dissociations may also be effected.

Of great importance is the process of hydration or the chemical combination of water in certain minerals. This change generally accompanies the oxidation of the rocks and causes even greater increase in volume than does the latter process. Some of the hills of Brazil are believed to have been increased in height by this means, which may be readily understood when it is learned that the transforming of granitic rocks into soil by hydration entails an increase in volume of 88 per cent.[1] The rocks of the Piedmont Plateau region of the eastern United States have been deeply affected by this alteration in their physical condition. For many feet below the surface there extends a zone of rock which has suffered hydration and consequent swelling of the altered minerals. When a block of this hydrated rock is brought to the surface it keeps its shape and compactness only a short time; soon it crumbles away like a piece of air-slaked lime.

Besides the chemical agents which the rain washes and absorbs from the atmosphere there are powerful organic acids which the decaying vegetable and animal remains lying on and in the soil furnish to the waters percolating through it. These substances added to the water make the moisture which pervades all rocks and soils a very powerful and active agent in their disintegration. Clearly a district whose rock foundations are thus weakened by chemical and physical changes will offer but slight resistance to the attacks of rain, rivers and waves.

The rich soil and the even-floored valleys which characterize limestone and marble areas have resulted from the rapid and uniform removal of the carbonate of lime in solution in the soil-water and by the streams. It has been estimated that 275 tons of lime or calcium carbonate are annually dissolved from every square mile of the Calciferous limestone of the Appalachian region, and this limestone is but one of several different beds which occur in that region. But these solvent waters attack not alone the yielding limestones. Granite, gneiss, sandstones, shales, quartzites, all yield more or less readily to its attacks, and none escape without some loss.

Striking illustrations of the great solvent power of the waters of the earth's surface are furnished by the corroded surfaces of quartzites, metamorphosed siliceous conglomerates and other siliceous rocks. One need but to go on an excursion to the rocks of Deer creek in Harford county, and, climbing to the summit of the ridge, stand on the projecting ledge which overlooks the gorge from the south in order

[1] Merrill, op. cit. p. 188.

to have under his very feet a striking illustration of the inability of the resistant silica or quartz to withstand the great solvent. The rocks at this point are a fine-grained siliceous sandstone and a quartz conglomerate which have been much metamorphosed or mineralogically altered under great pressure, and have, in consequence, been thoroughly impregnated with a secondary deposit of silica. Such rocks form one of the most resistant combinations which the earth presents to the elements, yet the surface of this ledge is pitted with shallow basins from three inches to one and a half feet in diameter and one to three inches in depth, which have been gradually dissolved out by the standing rain water. Little runways or channels generally connect one basin with another or lead out to the edge of the cliff. No lichens of corresponding sizes grow on these rocks, and the slight undercutting of the walls of the basins at a line corresponding to the average level of the water indicate that they are the product of aqueous solution. Similar basins and channels may also be seen developed on the exposed crests and ledges of quartzitic sandstones which form Dan's mountain, Backbone mountain and a number of other localities in this state and elsewhere. With examples of such intensity of action it is less surprising to learn that T. Mellard Reade[1] finds data according to which he estimates that England and Wales annually lose through solution an average of 143.5 tons of material per square mile, and this does not apply only in limestone areas but is an average for all the different rocks.

Powerful and important as are the chemical ways in which water aids in denuding the land, the mechanical action of this agent is of equal importance and generally much more striking. One of the important processes of denudation is the splitting of rocks by frost action. All rocks are more or less porous and contain water, while most rock masses are traversed by numerous sets of cracks called joints, and by finer partings, rifts, seams or the like, all of which permit water to penetrate below the surface of the ledges. The elevated and exposed peaks of all zones and the ordinary ledges of the Temperate and Arctic zones are all subject to frosts and thaws intermittently during the winter months. These sharp, sudden frosts

[1] Merrill, op. cit. p. 194.

seize on the water imprisoned in the pores, joints and cracks of the rocks and by the expansion, which results in the formation of ice, cause a tremendous pressure to be exerted against the sides of the confining crevices. The great power exerted by this expansion of freezing water may be judged from the calculation that the walls of a crevice which thus confines frozen water are subject to a pressure per square foot equal to the weight of a column of ice one mile high or about 150 tons. Successive frosts and thaws are thus able to split off innumerable small chips and to gradually work out huge blocks which later are by the same process reduced to sand. Pike's Peak in Colorado, a granitic mass, has large talus slopes wholly composed of angular fragments which have been thus split from its crest and sides. All the mountains and ridges of western or Appalachian Maryland show the results of the same action. Along the roadway to High Rock and Mt. Quirauk in the Blue Ridge may be seen fine examples of talus slopes composed of huge frost-riven fragments of the enduring quartzite which makes the ridge. Steep slopes of such fragments line either side of "The Narrows," as the gorge of Will's creek at Cumberland is called, and there furnish, already quarried, inexhaustible materials for constructive purposes and for railroad ballast.

Frost action does not stop with the breaking down of lofty mountains or scarred precipices, but continues to work over the coarse material thus furnished, converting it finally, with the help of the agents already noticed, into the rich soils which support the crops of the country; thus, although frequently damaging to a few crops, it is of the greatest help to the farmer, since it readily reduces almost to powder the stones of his fields and continually enriches the soil by bringing to it new material from the original sources. A striking illustration of the splitting action of freezing waters is found ready at hand in the unsightly scaling which disfigures houses and trimmings of sandstone. The sandstone commonly used in Maryland is very porous and readily absorbs water during a rain or snowstorm. If a frost comes while the stone is thus soaked the freezing of the imprisoned water causes it to split or scale off, particularly in a direction parallel with the original bedding. Grace Episcopal Church, Baltimore, gives the best illustration possible of this process and its results.

Most of the processes which have been discussed so far have resulted in the disintegration or solution of the rocks of the earth's crust, thus preparing them for transportation. We have also to consider water as an agent of denudation and transportation combined. There are two forms of water which act in this double capacity, namely, ice in the shape of glaciers and floating ice and liquid water in the rills, brooks, rivers, lakes and oceans.

A portion of the water which falls as rain sinks into the soil and rocks as has been shown; a very fair proportion is evaporated and goes back into the air again; and a comparatively small proportion runs off on the surface. The latter portion is familiar to most of us, as the formation and growth of rills during a shower is easily observed. No rill, however small, runs down even a sodded slope without catching up at some point a fragment or two of soil. Soon the rills unite to form a small run which rushes downward still faster, carrying the fragments which loaded the rills and acquiring more soil and pebbles by its own strength. In this way the stream carves for itself a gully or channel. The waters gather into brooks and creeks and rivers, each increase in size and volume being accompanied by an increase in the amount of soil and rock debris which the streams bear onward. As has been shown, the streams thus transport and carry away from the surface of the land not only what has been broken off mechanically by frost, wind, temperature-changes, etc., but also what the waters succeed in dissolving away by chemical means. The streams not only carry away the soils and dislodged fragments of rock, but also do some breaking themselves. The small rill or rivulet carries fine grains of sand which it knocks and pushes against the soil and rocks over which it flows; the brook, with the larger volume, rolls pebbles along its course; and the mountain torrent transports large boulders. These rock-fragments the streams use as tools which they continually hurl against the bottom and sides of their channels, thus wearing away the rocks and cutting their valleys deeper and deeper. In the course of down-cutting untold numbers of boulders are reduced to powder, but eventually the channel is cut almost to the level of the sea.

Thus the rains are working to wear away the general surface of the land by washing down the soils and to deepen the streams by giving means of transportation and movement to their tools.

The snow collects on lofty mountain tops, and gradually sliding down under the force of gravity, begins to solidify into the ice of glaciers. The glaciers moving slowly, perhaps not more than one inch in a day, push on irresistibly until they melt away. Rocks roll down the slopes of mountains, and lodging on the glacier gradually melt their way down to the bottom of the ice-river, and there, with other fragments which the moving ice has plucked from its bed, serve as cutting tools whereby the glacier deepens and widens its channel. When glaciers combine and grow to such a size that they cover the half of a continent, as was recently the case in North America and Europe, they scrape off the loose rock and soil and grind and polish the rocky ledges below until they gradually wear away the surface.

On the seashore the waves of the ocean are continually beating against the land. The great breakers of storms hurl many tons of water against the projecting rocks of the coast, and the water penetrating every crack and crevice subjects these rocks to enormous hydrostatic pressure. In this way great and small blocks are gradually split from the cliffs and reefs and fall to the foot of the beach. Here the waves seize the fragments which they have broken off above, and hurl them against the rocks below. Thus the ramparts of the land are gradually battered down and undermined, and broad submarine shelves appear. On sandy coasts the weak cliffs give way rapidly before the waves and are driven back until the sands which they have furnished form a broad shallow shelf on which the waves must break until they have removed it and can again reach the cliffs.

### *Organic Processes.*

Organisms aid the general reduction of the land in various ways which, although often of small moment individually, are very powerful taken as a whole. The fine frost- or heat-riven fragments of the rock suffice to support at first a few simple plants and lichens. These send out their roots in search of food and penetrate the fine crevices of the rocks. The roots, continuing to grow, split the rock-pieces apart as they increase in size and thus furnish more material for the soil in which they grow. When the trees strike root in the soil collected in rock-crevices their roots often exert power enough during their growth to split off large boulders. Every plant clinging to the face of a cliff, every clump of moss or lichen fastened to a rock, is aiding in the breaking down of the rock by its growing roots and by the various acids which it produces. Even the minute organisms known as bacteria, by reason of the nitric acid which they liberate in the course of their growth and their presence in countless myriads throughout the cracks of the rocks, exert a not inconsiderable disintegrating influence upon the rocks in which they lodge. Merrill says (p. 203), "The organisms act even upon the most minute fragments, reducing them continually to smaller and smaller sizes."

To the accumulated soil are added, in the course of time, the remains of plants and animals, which yield in the process of decay various acids, that are taken up by percolating waters and further distributed through the rocks, where they aid in their chemical and mechanical disintegration. The evacuations of various animals, such as ants, also afford supplies of disintegrating acids.

Burrowing animals, such as rabbits, squirrels, prairie-dogs, earthworms and the like give important aid to the denuding and transporting agents by keeping the soil loosened and pervious to rain and moisture. Darwin found that earthworms, by continually transporting earth to the surface from their burrows beneath the large stones in the pastures, have been largely instrumental in the gradual burial of these rocks, thus materially aiding in the disintegration of such masses. Considerable quantities of decaying organic matter, such as litters of dead leaves, scraps of food, excrement and so on are also generally to be found in animal burrows and thus another very fruitful source of organic acids is afforded.

*Summary.*

From the foregoing it appears that a multitude of agents and processes are incessantly at work all about us, tending to break down the rocks and to wash the debris thus produced into the valleys and thence to the sea. The gases of the air, the wind, the temperature changes accompanying the days and seasons, combined with the chemical and mechanical actions of the waters on the earth's surface and the organisms which live thereon, are all striving to reduce the lands that stand above the sea. Clearly, if these forces, unmodified and undiminished, continued to act indefinitely, the continents and islands would not long remain above sea-level. Since the subaërial agencies would work much more rapidly than the waves they would first be reduced to smooth, featureless tracts, whose inclination seaward would be just sufficient to carry off the water which falls as rain. Then they would gradually yield to the attacks of the waves, and in the end would be planed off to more or less even surfaces some feet below low tide, forming wave-cut submarine benches and platforms. Geikie[1] estimates that the continent of Europe would be reduced to sea-level in about four million years if exposed for that length of time to the attack of atmosphere, rain, and rivers, and supposing these to work at the same rate that they do to-day. In the same period of time the sea-waves would cut away a strip of land along the shore less than one hundred miles wide, considering them to advance at the rapid rate of ten feet per century. Another authority[2] estimates that the waves remove annually one cubic kilometer of material from the land, while the subaërial agencies are carrying away not less than fifteen times as much.

When all the above considerations are kept in view, together with the fact that the surface of the land is well supplied not only with high hills and minor elevations, but also with many lofty mountain chains and plateaus, it is patent that there must be constructional processes at work counteracting the destructional ones which have been described. They will be discussed in the following pages.

[1] Geikie, A. "Textbook," 3rd ed. p. 467.
[2] de Lapparent, quoted in Scott, W. B. "An introduction to Geology." pp. 303-4.

## PROCESSES OF CONSTRUCTION.

### *Crustal Movements.*

The most important of the processes which are at work counteracting the destructive effects of denudation are those movements of the earth's crust which are tending to elevate it above the level of the sea.

These movements are of two general kinds or classes. One class includes those movements of the earth's crust which extend over areas of continental extent and do not result in the appreciable dislocation of the strata through folding or tilting. These movements are sometimes called *epeirogenic.*

The second class of movements and dislocations affect restricted portions of the continental plateau and are expressed as foldings, tiltings and faultings of the different crustal elements. They are the fundamental movements whereby mountains attain their elevation above sea-level. Such movements are therefore called *orogenic* or mountain-making. Many familiar examples of such movements and dislocations might be cited. The best known to Marylanders are the long ridges and mountains of the Appalachian province of the state formed by the folding and faulting of the Paleozoic strata of that district. The Blue Ridge also is the result of the pushing of a big block of hard sandstone and volcanic rocks over the easily eroded limestone of the Cumberland or Hagerstown valley. In the west the Sierra Nevada and the Great Basin ranges are formed of huge blocks which have been broken or faulted and then tipped up so that one edge of the block forms the crest of the mountain range. All such mountains have had their present physiognomies carved out during and since their elevation by the various denuding agencies above described.

### *Volcanic Eruptions.*

The ejection of lava, volcanic ashes, scoriae and the like from volcanic vents are very effective and important agents of construction in some localities, but they have not recently affected the surface configuration of Maryland. The sheets of diabase which characterize the sandstones of the Newark formation, and the acid and basic volcanics of the Blue Ridge district show, however, that volcanic activities were present in Maryland in past geological ages.

*Subaërial Processes of Construction.*

In discussing the denudation of the land, several references were made that indicate the *constructional* activities of agents and processes mainly and ultimately destructive.

Thus the wind-whirled sand which carves out the standing rocks of the shores is spread over the surface or formed into dunes so common and characteristic of the whole Atlantic coast of America. The sand blown from the beaches is also often dropped in great quantities into the lagoons behind them and thus becomes an important factor in bringing about their conversion into dry land.

Aqueous agents are also active builders. Deposits from evaporating waters about mineral hot springs often build important topographic features such as the great terraces and basins of the Yellowstone National Park. The mechanical deposits from running or standing waters are the most numerous and important of the constructional forms built by water. Among these are the talus-cones and flood-plains and deltas of rivers, and the beaches, spits and bars produced by wave action in lakes and seas. The great ice-sheet of the Glacial Period, and the smaller glaciers of lofty mountain areas have left very striking constructional topography in the form of terminal moraines, eskers, drumlins and kames. From these examples it may be seen that water in its various forms has constructive as well as destructive effects.

*Organic Processes.*

Small plants living in the waters of various thermal springs are now known to be very effective in promoting chemical deposits. On the slopes of dunes and on other sandy areas are coarse grasses and shrubs and sometimes even trees that, on account of the binding power of their roots, protect the sands from further removal. Similarly, the grasses and sedges of the mud-flats and marshes, by retarding the currents flowing over them, cause the deposition of silt, while their long roots, matting together, convert the mud thus deposited into a more or less resistant mass.

### *Summary.*

Constructional processes thus fall into two great divisions: first, those which originate in movements of the earth's crust resulting in uplift, and second, those which accompany the progressive denudation of the land. The essential process which must precede all degradation is uplift, and this may either be continental (epeirogenic) or mountain-forming (orogenic). These movements, gradually progressing, permit the agents of denudation to become effective, and thus minor constructional features, such as dunes, flood-plains, deltas and the like are produced by agents which are on the whole destructional in their results. These minor features, however, are not as permanent as the hills and mountains which are carved out of the uplifted areas.

It is apparent, then, that there are upward movements which counterbalance the wearing away of the land's surface, and that these uplifts are at present somewhat in excess of the downward tendency. This is more clearly seen by the study of geographical boundaries as they existed in former geological periods. In the course of ages America has grown to its present size from being comparatively small in area and confined to islands over what is now Canada, northern central New York and the Piedmont Plateau of the Atlantic Slope. The very last emergence added a strip of land one hundred to two hundred miles wide to the eastern coast of North America from Long Island south to Mexico and Yucatan.

Although the study of ancient geographical boundaries or paleogeography is very interesting, and there is much material within the state of Maryland for such investigations, this will be left for a future paper. At present the development of certain typical river systems and the topography which they have carved out are to be considered.

## DRAINAGE DEVELOPMENT.

### *A Topographic Cycle.*

It seems possible in the light of the more recent investigations in physiography to deduce certain general laws concerning the development of the relief of the earth's features. Those districts which can be shown by geological evidence to have been long above sea-level are generally found to have mild forms of relief, while the recent elevations commonly have strongly marked topographic characters. Such regions, for example, as the Piedmont Plateau of the Atlantic Slope of North America, the Scandinavian peninsula, portions of central Germany and northern France, have stood at relatively the same elevation above sea-level for long periods and are found to have a mild and rounded topography, while the Alps, the Himalayas, the Coast Ranges and the Grand Canyon of the Colorado have been carved out during geologically recent times and are regions of strong relief.

Among the various cases just cited different grades or degrees of topographic relief may be shown to exist. Thus, for example, the geological date of uplift of the Himalayas is known to be earlier than that of the Coast Range, and an examination of the drainage reveals the fact that the streams of the former district are somewhat more intricate on account of the longer time which they have had to extend their branches. Again, in the recent Red River basin of the North, the streams are still less minutely branched than are those of the Coast Range.

If now the drainage of a newly emerged or recently elevated district be followed through the several periods of its development, it is possible to find all these various types of drainage occurring in a natural and appropriate sequence. As the rains fall upon the slightly uneven surface of the old sea-floor the waters gather in the inequalities of the surface, forming lakes or, combining as streams, run down the steepest slopes they can find to the sea. The directions taken by these newly-formed streams are wholly consequent upon the original inequalities of the surface and its slope. It will appear later that such streams whose courses are determined by, or coincident with, courses which would result from, original configurations of the surface are common enough to be classed together as a type. They are, for convenience, called *consequent streams.*

At first these consequent streams are small in volume, but repeated rains gradually increase the size of the streams and they begin to carry away the debris which the elements and their own powers loosen from the surface. Thus efficient tools are provided, and the streams begin to sink their channels rapidly, since along those lines are concentrated the greatest activities of the running waters. The first result is the excavation of a deep canyon or gorge, this work beginning at the mouths of the streams and progressing rapidly headwards. While the narrow canyon is being pushed towards the head of the stream, along the lower course the gorge is beginning to widen as the result of the action of frost and rains. Widening is greatest at the top of the canyon, which is the portion first and longest exposed to the weather, and, except at the extreme upper end, where the gorge is youngest, its cross-section will reveal a flaring top.

The stream will continue to cut down its channel until it has produced a slope whose inclination seaward is the minimum required to carry down the water. When such a slope is reached, then the stream begins to lose its downward cutting powers and works more and more against the sides of the canyon, and we thus have a second reason for finding the canyon wider at the mouth of the stream. The deepening of the main channel goes on faster than does that of the side streams, but as the accomplished grade progresses up stream the tributaries, heretofore unable to keep up with the rapid down-cutting, now begin to adjust their slopes also. Until the lower portions of main and side streams are thus adjusted, however, the as yet unaffected headwaters do not feel the effect of the uplift and can accomplish but little in the way of erosion. There is not, then, at this stage in development, a large number of side streams, and the divides are broad, flat, poorly drained, and sometimes even marshy. The whole district has an appearance somewhat like that shown in Fig. 1.

As this general stage in the drainage development is the one passed through immediately succeeding the birth of the new land it may be appropriately termed *Infancy*. It is by no means an imaginary topographic phase. Many illustrations of such topography could be brought forward. The drainage and topography of the Coastal Plain, particularly that portion lying in Maryland, still carries the ear-marks of this period in its development. The wandering courses of the Chester, the Choptank, the Patuxent, the lower Potomac, etc.; the deep gorges now half filled by the waters of the sea and the bay, which have been cut by the streams of southern Maryland; and the level remnants of the original Lafayette surface, which are still to be found at points remote from the attacks of the largest

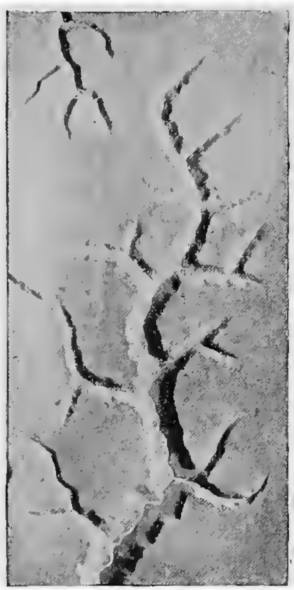




FIG. 1.—View of model illustrating topographic youth.

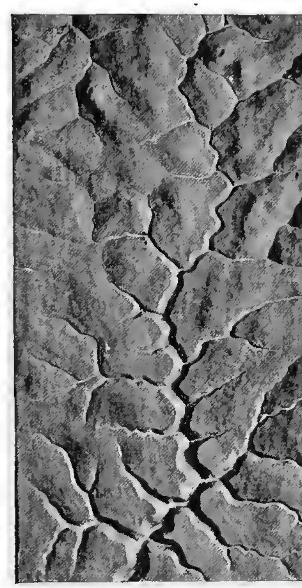




FIG. 2.—View of model illustrating revived topography.

streams, all indicate that the Coastal Plain is not long past its infancy. The classic example of infantile drainage and topography is that great gorge already referred to, the Grand Canyon of the Colorado, but it is not wholly typical on account of the desert conditions.

The rapidly increasing number of small streams along the sides of the canyons, the continued beating of the rains and the winds, in fact, all the active processes of denudation, since they never cease in their activity, do not permit the newly started streams to retain such infantile characters long. The steep walls are gradually worn back, and the few original consequent tributary streams, having cut down their lower channels to the grade of the main stream, begin to push back their headwaters. New side streams spring up along the walls and slopes of the gorge, cutting deep scars and seams in them, and thus hasten their recession. As the number of tributaries increases the broad flat divides are narrowed and even begin to lose their flatness. The lakes which formed at first have their outlets cut down and are drained, while the channels of the older streams, which were rough and broken by falls and rapids, gradually lose their inequalities. The volume of the main stream is somewhat increased by the growing number of side branches, but as each one of these comes down laden with the debris which its active little headwaters and its steep banks furnish, a great load is soon added to it. All of this load the larger stream cannot manage to transport, and so some portion is dropped at the mouths of the several tributaries, forming cone-like alluvial deposits that project into the main valley, while part is taken by the master stream and is used by it to steepen its slope, thus enabling it to carry off a greater load. Many streams in this stage may be found among the high lands of the Sierras, the Himalayas and other regions of plentiful rainfall and recent elevation. Excellent examples may be found in certain portions of Southern Maryland. In St. Mary's county numbers of the southwestward flowing streams show these adolescent features, with the over-loading of the main stream and consequent flood-plain building.

The constant increase of the catchment area by reason of the ever growing number of streams and the pushing back of the headwaters, continues until the divides between opposing streams, whether of the same or of different drainage systems, are sharp and steep. The ramifying branches have sought out every square mile of territory, so that the whole region is completely drained. The small headstreams thus having no new territory to conquer by linear development begin to reduce the steepness of their own slopes, to soften their valley sides, and to reduce and round off a little the tops of the hills. Thus the amount of mechanical sediment brought to the larger streams decreases while the volume of water still remains about the same. The main channels smoothed out still more are so far reduced that they describe smooth regular curves from source to mouth. Up to this time the slope of the river channels has been slowly changing, but it now reaches a period of comparative stability, since the changes in load and in volume, which are the factors determining the curve, are very much slower hereafter. The channel slopes are now more permanently suited to the needs of the streams and the latter may be said to have established graded channels. The accompanying figure shows the slope to be steepest at the source, but to rapidly decrease to a midway point whence it is of constantly but very gently decreasing fall to the mouth. As all the streams gradually approach such a graded condition, the inter-stream areas forming the divides also gradually wear down. Such an area is included within the

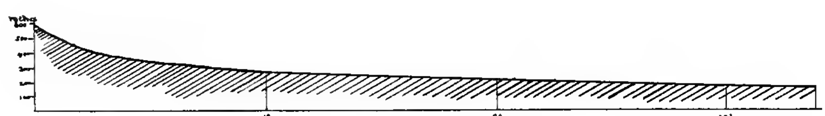


FIG. 3.—A normal stream profile (after Penck).

boundaries of the Piedmont Plateau on Plate III. Similar topography characterizes most of Northern Virginia and large portions of Eastern New England. The country and its drainage may be said to have reached its *Maturity*.

The gradual change in topography and in drainage which have just been briefly sketched presupposes, first of all, that the land and sea have remained constant to each other long enough to permit such development to occur. This supposition is not always justifiable, since multitudes of cases can be cited to show that after a period of rest long enough to permit of the topography developing to some stage earlier even than Maturity, earth movements have closed what may be called the current cycle and have inaugurated a new one. In order to make the series of topographic forms complete, however, some students have carried the scheme beyond the stage of Maturity and described yet another and final stage which has been likened to *Old Age*.

Suppose that after Maturity is reached, the same conditions endure for an indefinite period. The streams would still continue to deepen their channels although at an ever decreasing rate. The hills and mountains would gradually sink lower and yet lower, yielding now more to the solvent action of the waters charged as they would be with acids from the mantle of soil and vegetation which covers everything. Finally all slopes would be reduced to the lowest possible angles and the divides also would be very insignificant, except at points far from the mouths of the streams. The lowest zone would be along the sea-coast, where the land would be reduced quite to sea-level. From here inland there would be the slightest possible rise in order to permit the rains to really drain away and not gather into stagnant pools. The whole district would be nearly featureless and so closely approach a plain in appearance and contour that it might appropriately be called *an almost-plain* or *peneplain,* just as an almost-island is a peninsula.

It is obvious that the lowest level to which a land can be worn down by stream action is sea-level, and even this can never be reached except at the very shores, since some slope is needed to carry off the water. Therefore the ocean is called *the great base-level,* or the base down to whose level all the forces of Erosion or Denudation are working to reduce the land. *Local base-levels* may exist for a time, such as the level of a lake, which is the base-level for streams entering it, or the level of a stream where it crosses an unusually resistant stratum, which may be the base-level for its tributaries above this point. But eventually all the streams are controlled by the level of the sea. Such an enormous duration of time, throughout which the position of the land would have to remain fixed with reference to the sea-level, would be required, however, to permit of the production of such a complete peneplain, that there is scarcely any warrant for supposing that such a condition has often existed. Nowhere to-day can an example of such a topographic feature be found.

On the contrary, everywhere there is evidence to show that the land and sea do not long continue constant to each other. Young as are the Coast Ranges of California, they had, since their elevation, attained very nearly to ripe Maturity, when great subsidences took place, drowning part of them. These accidents again were recently followed by successive lesser re-elevations. The eastern coast of North America has suffered repeated elevations and subsidences since the period of the last great elevations of the Sierra Nevada, and is still undergoing slight oscillatory movements. Other instances might be cited to show that the chances are probably small for a locality to reach even to the perfection of well-matured topography.[1]

Although the topographic cycle has perhaps never had an opportunity to run its full course, yet it is convenient for the purposes of understanding and explaining topographic forms to retain the conception of a complete cycle, which might be renewed, if, after attaining to the stage of a peneplain, the land were again elevated and the streams commenced their tasks anew. As we have seen, however, the rule is that at some stage in the ideal cycle the march of development will be interrupted. Such interruption may result from one or several causes. The most common interruptions come from re-elevation of the land, whereby the streams receive increased energy, or from depression, which allows the sea to invade a portion of what was dry land and reduce the energy of the streams by decreasing the height from which they have to fall to reach sea-level. When by reason of the rise of the land the streams renew the vigor of their own cutting, and begin to cut canyons below the general surface which they have before produced, they are said to be *revived.* The same phenomenon would be produced if, after long delay, the master stream of some system should succeed in cutting through a stubborn ledge and begin to work rapidly down through a more yielding understratum. It will appear farther on that most of Maryland's streams show the reviving effects of re-elevation. The illustration forming Fig. 2 shows a district of *revived drainage.* Depression whereby the lower courses of most of the rivers are submerged beneath the sea hastens the reduction of what is left above sea-level, and by decreasing the slope of the lower courses often

[1] See R. S. Tarr, "The Peneplain." Amer. Geol., vol. xxi, 1898. pp. 351, et seq.

causes the building of flood-plains at these points. The coasts of Maine, of Norway, and of Maryland afford excellent examples of such topography, which is called *drowned.*

### *Migration of Divides.*

The progressive development of a piece of country through the stages of a Topographic Cycle is accompanied by many interesting processes, some of which will be considered in this and the following section.

When the broad flat divide which characterizes the infancy of stream growth is converted to the sharp serrated crests and ridges of earliest maturity, the streams, which before were battling against a common enemy, viz. the unreduced land mass lying between them, are then brought into closer rivalry. Each stream heading against a divide is endeavoring to wear it away and to gain more drainage area. If the streams are pretty evenly matched, then the divide must gradually sink down, until it becomes a low ridge almost exactly beneath the line along which the headwaters of the opposing streams first met on the surface of the plateau. Should it happen, however, that the streams on one side of the crest had an advantage over the opposing set then the rocks would be worn away unevenly on the two slopes; the stronger streams would wear away their side faster and the divide would move towards the weaker set of streams.

There are many ways in which one set of streams may come to have more power than an opposing set. The favored streams may have a shorter course to the sea, thus giving them a steeper slope, or what may amount to the same thing, the course may lie on softer rocks which, being more nearly reduced to the sea-level or base-level along the lower course, concentrate the greatest possible amount of steep slope at the headwaters. This is excellently illustrated in Maryland by the contrast in slope which exists between the tributaries of the Monocacy, a stream situated on easily eroded slates, sandstones and limestones, and the main streams of the Patapsco, the Patuxent and other rivers which have to cross the resistant gneisses and other crystalline rocks of central Maryland. Again, greater rainfall will give to one side larger volume and greater cutting powers. Excellent illustrations of the advantage gained in the latter way are furnished by the streams on the western slopes of the Cascade, and the Sierra Nevada, and on eastern slopes of the Andes in equatorial America. Also a tilting of the land in the direction of the favored stream, by increasing the slope of the one and decreasing that of the other, may give advantage sufficient to cause a shifting of the divide. This particular method has been appealed to farther on in explaining certain anomalies in the drainage of the Maryland Coastal Plain.

Another way by which divides are caused to shift or change their positions arises from the attitude of the rocks. In districts underlain

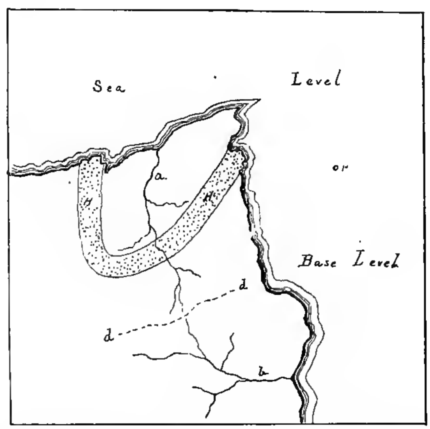



FIG. 4.—Diagram illustrating a simple shifting of divides.

by layers of alternating hard and soft rocks, which are inclined at an angle to the horizontal, the divides first tend to become located upon the hard rocks. For example if, as may easily be the case at birth, certain streams, such as *a* in Fig. 4, are so located that they cross the hard layers, then, because of the hindrance which they thus meet with, they can reduce their channels but slowly. This gives an advantage to streams located like *b*, which, being on yielding rocks, can cut down more rapidly. Therefore *a* must slowly retreat and *b* advance step by step until the divide *d-d* is located upon the hard band *H-H*. Once thus located, the divide will not tend to move one side or the other, unless the hard layer be inclined, as represented in Fig. 5. In such an event it is evident that, as the land is denuded, the divide will follow down the dip of the strata, assuming the positions $D$, $D'$, $D''$ successively. The tendency in all cases is to maintain divides upon the most resistant strata. Many instances of such a cataclinal or down-the-dip shifting of divides are furnished by the

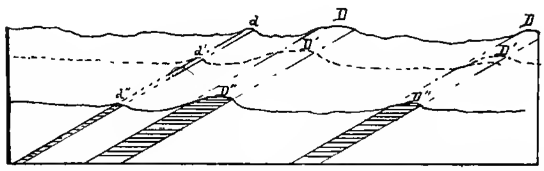


FIG. 5.—Diagram illustrating shifting of divide in a region of tilted rocks.

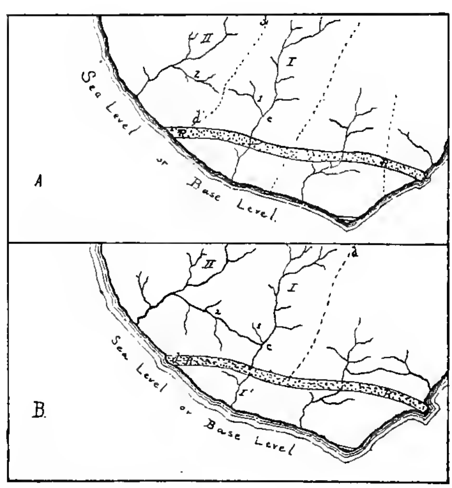


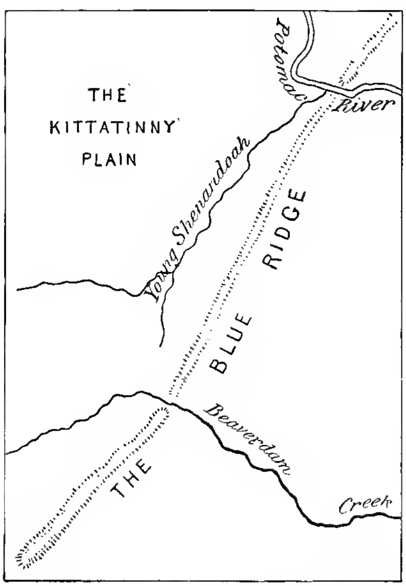

FIG. 6.—Diagram illustrating shifting of divides through stream capture.

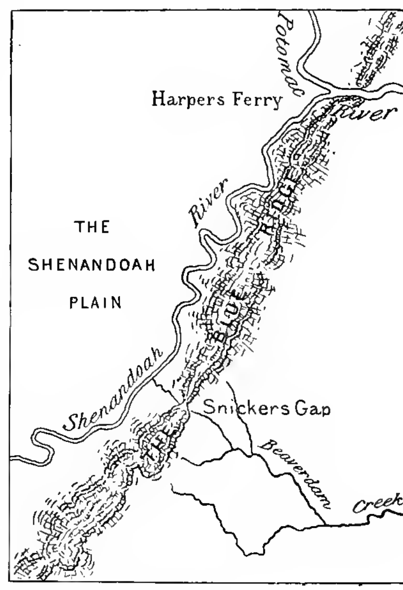
Appalachian Province of Maryland. Shriver's Ridge, Big Savage mountain, Winding Ridge, Catoctin mountain and many smaller mountains are examples of such divides.

The manner in which divides or watersheds migrate has been brought about generally by a slow, gradual shifting. Divides between two river systems or two parts of the same system may at times shift suddenly. Thus, as shown in Fig. 6, one stream *I*, perhaps the larger, has to cross a very refractory band *R* on its way to the sea, while the other stream *II* traverses yielding rocks along its whole course. In the course of time the second stream *II*, by reason of its easier path, will reduce its channel to a much lower level than it is possible for the first stream *I* to do along that portion of its course above *R*. Thus more power is gained for the side streams of *II*, and they are enabled to push back the divides until *I* has been intercepted at *c*. Owing to the low level of the channel of *II* and its tributary 2, *I* is turned into the valley of 2, leaving its lower course to flow on as a shriveled, *beheaded* stream. This change in river courses shifts the divide gradually at first, then with a bound from *d-d* to *R*, again illustrating the law that hard rocks tend to form divides, soft rocks to form valleys. When the arrangement of the streams is not in accord with this the conditions may be regarded as anomalous and disturbing, or modifying factors may be looked for.

Many illustrations of such cases of river piracy and capture can be found in the Appalachian region of eastern North America. A single example found in the neighborhood of Harper's Ferry may be cited here. Others will be considered when the Appalachian Province of Maryland is described. In Fig. 7 is represented a bit of drainage along what is now the Shenandoah Valley and the Blue Ridge. At the period represented the whole Atlantic slope probably appeared as a broad, gently rolling plain. This plain was but slightly interrupted by the low crest of the Blue Ridge which the Potomac river and Beaver Dam creek crossed through low shallow water-gaps. Beyond the eastern limits of the figure Beaver Dam creek joined the Potomac. The young Shenandoah had begun to develop along the broad band of limestones which lie just west of the hard quartzites and volcanic rocks forming the Blue Ridge.

Shortly after the time represented in Fig. 7 the whole eastern slope of North America was tilted and raised. This elevation revived the streams and they began first to deepen their channels and then to push back their headwaters and sidestreams. The Potomac, with its large volume, rapidly sank its channel through both the limestone and the hard rocks of the Blue Ridge. Thus the mouth of the Shenandoah was lowered and this stream began to push back its drainage basin. Beaver Dam creek also felt the effects of the revival, and would have done battle with the growing Shenandoah for the mastery of the area west of the Blue Ridge; but the creek was seriously handicapped, for it could not work back faster than its small volume could cut down its gap in the Blue Ridge while the Shenandoah had the




From National Geographic Monographs, American Book Co.

FIG. 7. FIG. 8.

Examples of river piracy (after Willis).[1]

aid of the powerful Potomac. So it resulted that the Shenandoah worked faster than Beaver Dam creek was able to do, and finally capturing the headwaters of the latter stream led them off to the northeast, leaving the beheaded stream to continue with the Blue Ridge for its future western boundary. As the Shenandoah grew in vol-

[1] The Kittatinny Plain is referred to elsewhere in the text under the name of the Schooley Peneplain, a term earlier employed by Davis.

ume, by further captures of a like character, its valley deepened and widened up to the foot of the mountains; the gap in the Blue Ridge where Beaver Dam creek formerly crossed was left high and dry as a *wind-gap*, forming a deep notch in the crest of the Blue Ridge; and a small stream flowed westward from the edge of the gap down into the Shenandoah, taking a slope and direction exactly the reverse of the one formerly held by the creek. Thus was developed the later drainage shown in Fig. 8.

*Relations of Streams to Structure.*

In studying the location and migration of divides, it has been seen how much the streams are influenced by the relative positions of the yielding and the resistant rocks; how divides may change their positions and finally come to coincide with the bands of resistant rocks or with those rocks most favorably situated for resisting erosion. In the processes of divide-shifting, the streams which have the most favorable locations either as regards rocks or in relation to base level or both, have been found to be the most successful in extending and developing their courses. From these considerations it is to be expected that wherever the various strata are of varying degrees of resistance and are arranged in an orderly manner, as is the case in the Appalachian districts, there the streams are to be found expressing the arrangement of the strata as they come to the surface. The valleys would be located on the more yielding rocks, while the interstream areas and divides would be formed by the resistant strata.

The manner in which such arrangements are perfected is simple. As the newly exposed land rises higher and higher and the youthful streams born upon it cut deeper and deeper, they discover the various strata which form it. If the beds are horizontal and undisturbed, as is the case in the Coastal Plain, and approximately so in the Alleghany Plateau, then the surface of the land does not present long belts of various rocks but is largely covered by one stratum. In such a case a peculiarly irregular branching of streams which is uncontrolled by variations in rock character is developed. This class of streams, called *autogenous*, is specially described in the chapter on the Coastal Plain. It is also characteristic of West Virginia plateau districts.

When the new land emerges from the sea and is folded into long troughs and ridges, as was the case in the Appalachian district, the streams find very different conditions of development. They at first take courses consequent upon the folds of the strata and thus collect in the lowest troughs, passing from one trough to the next by the lowest sags in the dividing, arched ridges. As the streams cut deeper, the small consequent streams flowing down the sides of the long ridges, and the larger streams, where they flow through sags in the crests of the ridges, saw through the various strata and reveal the hard and soft, the resistant and the yielding layers. After these first cuts are made streams rapidly develop along the yielding bands, and, by the shifting of divides through capture, the rivers one by one come to be located on these strata. At various points the larger, streams, able to cut down rapidly, maintain the consequent positions which they assumed at birth and cross from one belt of soft rocks to another in spite of the hard intervening ridge. The valleys on the soft rocks which are opened up after the birth of the streams are called *subsequent* valleys, and their streams subsequent streams, because their origin is subsequent to that of the consequent streams. As the streams progress towards Maturity, further adjustments serve to bring nearly all of the earlier subsequent streams and each of the younger ones into close accord with the arrangement and structure of the strata. The resulting stream-pattern will thus clearly show the direction of the underlying rocks. In the Appalachians, where the strata lie in long parallel folds, the streams have developed into a peculiar pattern like that made by the branches of a grapevine on a trellis, which is sometimes spoken of as a *trellis* or *grapevine system.* Its characteristics are shown in the arrangement of Bluestone river in Fig. 9. The same illustration also shows, in its upper left-hand corner, the irregularly arranged drainage which has developed on the horizontal beds of the Cumberland Plateau lying northwest of Alleghany Front and beyond the Bluestone river.

Where the rocks are faulted and tilted instead of being regularly arched and folded, the streams also arrange themselves along subsequent courses, but as the relations of the various beds are not as regular as in the case of simply folded strata, the stream pattern is not usually as regular in its development.

In areas of crystalline and metamorphosed rocks which have lost all traces of stratigraphic relations but still retain their relative powers

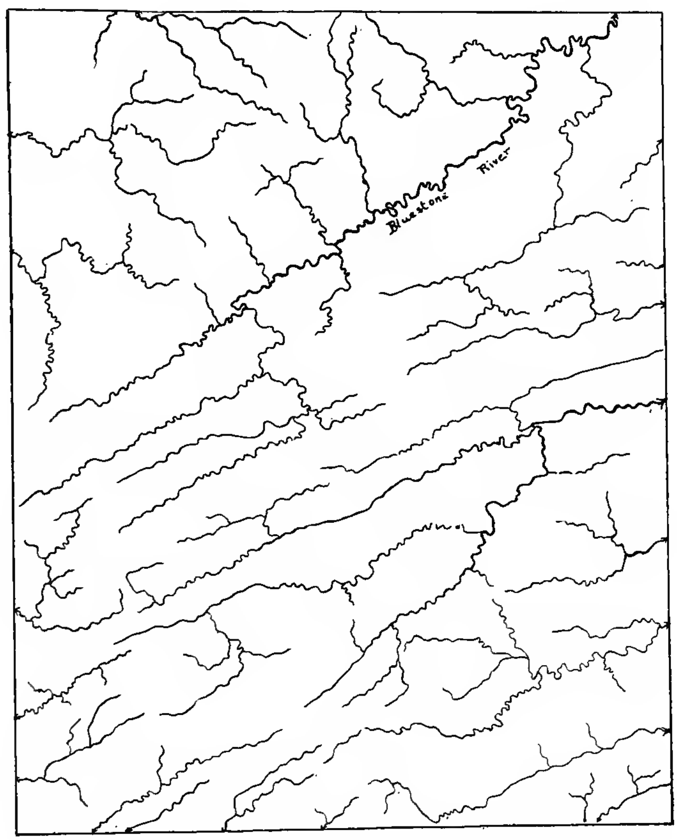



FIG. 9.—Streams adjusted to Appalachian structure (after Willis).

of resistance and some sort of banded arrangement, it is to be expected that the streams would still show certain adjustments to the rocks which they encounter. The particular features of such adjusted drainage will be treated of further on, but, in general, it may be said that the smaller streams and many of the larger ones would normally be found arranged in accordance with the directions of least resistance.

Although streams are normally affected by the rocks with which they come in contact in accordance with their degrees of resistance, these laws are not always operative. For example, the Potomac river cuts across the hard ledges of the Appalachian district fully as often as it turns and flows parallel with the direction of these ridges, in the valleys located on yielding strata. The points where this river cuts through the high ridges of hard conglomerate or sandstone are rarely points where it would have located if it had developed its position normally as many of its small tributaries have done. Various other features of the Potomac are anomalous, and to explain them it is necessary to go back to a time when, as will be explained in another place, the river was a large stream meandering from its source across a broad peneplain to the Atlantic. It has already been remarked above that when a land is reduced to a peneplain its streams are bordered by broad flood-plains in which they wander almost at random. It is not to be wondered at then that the Potomac, when it reached this stage, wandered from the well-adjusted course it had secured to itself during its maturity. A subsequent uplift set all the streams to cutting down and again caused the river to trench itself in its random, unadjusted course, thus preserving its senile wanderings for us to study. One way in which lack of harmony between streams and structure may be brought about is thus seen to be the wandering of streams during Old Age or under peneplain conditions.

When an area is wholly buried beneath a blanket of younger rocks or sediments, the streams which arise upon the new series of deposits take their courses quite independently of the structure of the rocks buried beneath them. Continued erosion may carry these streams down through the overlying strata upon the lower series and the stream courses will then be at variance with the arrangement of the latter rocks until sufficient time has elapsed to permit of a readjustment of the courses to the newly discovered conditions. Such a state of affairs will result when the streams at present draining the Coastal Plain blanket of sediments described in the next chapter, shall have cut through these and reached the underlying Piedmont rocks. This will be more quickly understood by referring to Figs. 11 and 12.

Another type of superposition is seen when a stream cuts down through a yielding stratum and comes in contact with a hard bed which it would have avoided had not the overlying softer bed tempted it. Illustrations of this are not infrequent in the Appalachians. It appears that Braddock's Run, near Cumberland, was for a short time thus superposed across Wills Mountain.

There are other ways in which a region formerly characterized by well-adjusted drainage may have its streams thrown out of adjustment. The country may be buried beneath extensive flows of lava, such as characterize the Deccan plateau of southwestern India or the great lava plains of the Snake river in Idaho. A great ice sheet, with its attendant deposits of till, sands, gravels and boulder clay, may so alter the face of the country, as has been the case in northern North America and Europe, that scarcely a single mile of any stream's course can now be pointed to with certainty as having been established before the advent of the ice. To this disturbing agency New England owes all its picturesque lakes and ponds and the many waterfalls along the altered courses of its rivers, which by their great resources of power for driving mills have made the Northern States the leading ones in manufacturing. Maryland can furnish, however, no examples of stream discordances resulting from either volcanic or glacial agencies. Several other causes of poorly adjusted streams might be mentioned, such as volcanic ash blankets, extensive loess and other alluvial deposits.

Having thus briefly reviewed the processes which control the topographic development of any area, we will now proceed to take up in particular the development of Maryland topography. The state, as remarked in a previous volume, may be divided into three general physiographic provinces, namely, the Coastal Plain, the Piedmont Plateau and the Appalachian Region. The boundaries of these provinces are represented on the map forming Plate III. To the consideration of each of these with their subdivisions separate chapters will be devoted, followed by a chapter in which special attention will be given to the Piedmont Plateau.

## The Coastal Plain Province.

### INTRODUCTION.

#### *General Structure.*

The eastern portion of the Atlantic Slope of North America, from Cape Cod to Florida and around the shores of the Gulf of Mexico, is bordered by a broad fringe of horizontally bedded deposits, extending from the Fall Line to the edge of the continental shelf, whose topographic characters and geological origin have won for it the name of the Coastal Plain. The researches of the stratigrapher and the paleontologist have unraveled the intricacies of the numerous beds which compose the Maryland area, and an account of their results is found in another place.[1] Here will be given only a brief sketch of those events in the history of the Coastal Plain which are most important from the geographical standpoint.

The Coastal Plain series begins with a group of formations, the Potomac Group, whose lithologic characters clearly indicate the conditions of the lands which they bordered. The lowest strata, Patuxent formation, composed of arkosic sands and clays, clearly show that the materials were derived from a deep mantle of disintegrated gneissic and phyllitic rocks such as that which now characterizes the surface of the Piedmont Plateau from Maryland southward. These beds everywhere rest upon the uneven surface of crystalline rocks which belong to the same series as those which constitute the Piedmont. This surface may, in fact, be traced as it passes out from beneath the sedimentary deposits and, bared of that covering, forms the rolling surface of the Piedmont Plateau of to-day. Detached portions of the sedimentary beds, as well as their general lithologic characters, indicate that they formerly extended farther westward than they do to-day. Their presence shows that hills now three or four hundred feet above sea-level once formed the ocean floor and were swept by waves, tides and currents.

Above the clays and arkose follow beds of clean white sands, and these again are overlain by lenses of iron-ore-bearing clays, Arundel formation, which were deposited in bogs that formed in depressions

[1] Maryland Geol. Survey, 1897, vol. i, p. 188 et seq.

of the older deposits. These depressions have the characters of old water-courses, and are interpreted as indicating a period of elevation above sea-level when the rains had opportunity to erode the surface of the earlier deposits. Interesting fossils in the shape of Dinosaurian skeletons found in these deposits show that great lizard-like creatures frequented the shores of the period.

Higher members of the Potomac group consist of variegated clays and coarse, irregularly bedded sands, Patapsco and Raritan formations. They are succeeded by sands and clays in alternating sequence, with slight variations in characters and progressing towards deposits of an argillaceous and finally glauconitic and marly character, Matawan, Monmouth, Rancocas and Pamunkey formations, which show that for some time true marine conditions prevailed in place of the shore conditions which produced the earliest formations. The transition from shore to deep-water conditions was preceded by a period of elevation during which a very considerable amount of erosion and valley-making went on. Smaller variations of level also took place from time to time and are recorded rather by the physical breaks and interruptions to deposition than by the lithological changes in the deposits.

Following the last period, the Pamunkey, which was characterized by deposits formed in moderately deep and quiet seas, came a period when the seas abounded in the microscopic plants called diatoms, and the deposits of this time are characterized by heavy accumulations of the siliceous skeletons of these small organisms. Following these came extensive deposits of clays and sands, crowded with infra-littoral organic remains, in which molluscan shells largely predominated. All of these deposits, representing several more or less clearly defined formations, are embraced in what is known as the Chesapeake Group. With the close of this period the deep-water history of this portion of the Coastal Plain ends. Elevation with landward depression succeeded the Chesapeake, during which the rocks of Maryland were subjected to a period of decay. These land conditions again gave way to littoral conditions. As the coastal border gradually sank, the transgressing line of ocean breakers rapidly worked over the materials already at hand in the older deposits and the decayed crystallines of the present eastern Piedmont belt. Thus was produced a sheet of gravels, sands and clays which spread out over the whole of the Coastal Plain province from Maryland southward to the Gulf.

The constituents of this formation, the Lafayette, change in character from one locality to another, and in many ways indicate that they were arranged by the restless waters of an ocean beach, thus distinguishing them from most of the earlier members of the series which, as already shown, have deep-water or estuarine characters.

Lafayette deposition was closed by an elevation which gradually elevated the Coastal Plain above the ocean, and enabled the Piedmont streams, not only to extend their courses eastward across the slowly emerging land surface, but also to cut deep gorges in the underlying strata. Besides the topographic record of the post-Lafayette emergence, evidence of the weathering influences of the atmosphere is not lacking in the general state of disintegration of the materials composing the formation.

Following the elevation and dissection of the Lafayette formation came a succession of depressions and elevations, accompanied in turn by deposition and denudation, that has produced a complicated history down to the present time. The deposits of this period have been described hitherto, so far as they have been recognized, as the Columbia formation, and appear at various elevations along the rivers, estuaries and inter-fluviatile districts of the Coastal Plain.

Professor R. D. Salisbury has published many interesting facts regarding the Coastal Plain gravels of New Jersey, and the investigations of the Maryland Geological Survey now in progress point to an early solution of the problems connected with the later history of the Coastal Plain in this state.

It appears, therefore, from what has been stated that the Coastal Plain is built up of a series of strata, for the most part composed of still unconsolidated materials arranged almost horizontally. Each successive sheet bears a portion of the geological and topographic record of the province, the whole showing that the land in this region has undergone many variations in altitude. Careful detailed study and mapping of the individual earlier members of this series will in the future yield interesting results and give many additional facts concerning the past topographic history of the old land area lying beneath and west of the province, but at present no attempt will be made to consider more than the comparatively recent history and topographic changes which have taken place within the area. Therefore, confining ourselves to that portion of the Coastal Plain which lies within the boundaries of Maryland, the next section will set forth the limits and subdivisions of the province.

### *Boundaries and Subdivisions.*

Before the post-Lafayette emergence, the Coastal Shelf or Coastal submarine Plain stretched from the unknown shore of those times eastward almost if not quite as far as the present edge of the continental shelf. We need not go back farther, however, for our present needs than to the middle of the Neocene, when the last extensive submergence took place. The exact extent of this submergence, during which the Lafayette formation was accumulated, is at present somewhat in doubt. Mr. A. Keith[1] has reported that remnants of this formation occur along the eastern foot of Catoctin mountain in Maryland and Virginia; but as the determination of the age of the deposit in those districts is based partly on lithologic characters and partly on the possibility of correlating certain topographic features of the western Piedmont Plateau with post-Lafayette formations in the Coastal Plain series, the date cannot be regarded as being definitely determined. Outliers of the Lafayette situated nearer the western boundary of the continuous strata, and of whose age there is no doubt, clearly show, however, that the submergence was very considerable in amount and in extent,[2] and that it was terminated by an uplift which raised the western portion of the coastal shelf higher above the sea-level than it stands to-day.

After the emergence, and as the result of it, the heretofore wholly

[1] A. Keith, "Geology of the Catoctin Belt," U. S. Geol. Surv., Fourteenth Ann. Rept., 1892-3, ii, p. 285.

[2] McGee, W J, "The Lafayette Formation," U. S. Geol. Surv., Twelfth Ann. Rept., 1890-1, i, pp. 508-511.

submerged Coastal Plain became divided into two great sections, which continue to the present time. These two sections were an eastern submerged portion, which will be referred to as the *submerged* or *submarine section*, and a western emergent portion, hereafter designated the *emerged* or *subaërial section.* The common boundary between these was the new shore line.

The term Coastal Plain as heretofore used by students of American geology has generally referred to that portion of the Coastal Plain which is called in this paper the subaërial section. Since the subaërial plain admits of comparatively easy investigation, because of the deep dissection it has undergone, and because it is habitable by Man, while the eastern submerged portion is wholly beyond our reach save through the revelations of the sections obtained from artesian well borings, very naturally our conception of the Coastal Plain has been bounded on the east by the Atlantic shore line. It is believed, however, that the proposed extension in the scope of the term Coastal Plain and its subdivision into a submarine and a subaërial portion is fully justified by the stratigraphy of the province and by the fundamental topographic form of the two divisions. To these two divisions of the Coastal Plain J. W. Powell[1] has added a third one, which is designated the *marsh portion*, recognizing as a separate subprovince that part of the plain "which is covered more or less intermittently with water by tides and storms."

The limits of the Coastal Plain, as thus newly defined, are on the east, the boundary of the coastal shelf, and on the west the intricately crenulate line which marks the boundary between the unconsolidated sands and clays of the Mesozoic and Cenozoic and the crystalline rocks of the Piedmont Plateau. West of this continuous boundary are scattered small detached areas, whose lithologic and stratigraphic characters show that they belong genetically to the Coastal Plain series, but have been separated from the main body by the activity of denuding processes since the province was raised above the sea-level.

[1] "The Physiography of the United States," 1896, p. 75.

## SUBMARINE DIVISION.

### *Boundaries.*

The submarine portion of the Coastal Plain may be considered as extending from the western shores of Sinepuxent and Chincoteague Bays eastward to the one hundred fathom line, which is very closely coincident with the eastern boundary of the continental shelf, and lies on the average about one hundred miles off shore.

### *The Sea Floor.*

Viewed as a whole, the surface of the submarine division of the coastal plain is a broad, even surface, gently sloping seaward and swarming with animal life. It is the feeding ground of most of our valuable sea fish and, therefore, the chief cruising ground for fishermen. Upon closer examination the shelf is seen to be very mildly and irregularly undulating, the swells and troughs becoming fewer

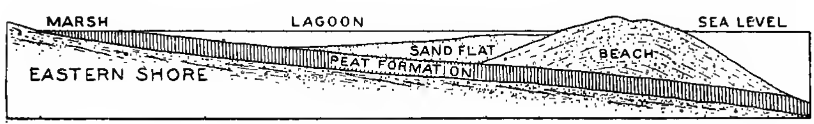



FIG. 10.—Section across off-shore beach and lagoon.

and milder seaward. These features are admirably shown on the U. S. Coast and Geodetic Survey charts.

### *Off-shore Beaches.*

Shoreward the even surface of the submarine plain is broken by the narrow bank of sands, which forms the long barren stretch of Sinepuxent Beach. This beach, and the long shallow bay behind it, see Fig. 10, are of particular interest, because they furnish excellent home examples of a type of coast line which characterizes North America from Long Island to Southern Mexico. This type is found wherever there is strong on-shore wave action across a shallow coastal shelf. As the great swells come in from the Atlantic the depth to which their vibrations disturb the ocean waters approaches more and more closely the actual depth of the water over the shelf. Ultimately, the disturbances begin to act on the bottom. The waves thus meet with considerable resistance in their lower sections, due to friction between the water particles and the sea floor. The result is that sand and mud are stirred up by the onward moving waves, and are carried shoreward with them until they break upon the beach. The breakers stir up still more sand by the impact of the mass of falling water. Many an unhappy bather who has had his mouth filled with the gritty water, as a wave, thus ladened, broke over him, will testify to its truth.

The sand stirred up by the waves and breakers is disposed of in several ways. Some of the material is carried along the shore by currents, much of it is thrown into a long heap or windrow landward, where the surf is breaking, and a portion is carried back to the deeper water by the undertow. The greatest advance in building beaches by such wave action is made by storm waves, whose greater power enables them to accomplish much in a short time. The great changes produced by storms are well recorded, because of their sudden appearance and often disastrous consequences to human interests, but although they are among the prime factors in producing coastal changes, they do not so strongly overbalance the less striking but long-continued activity of other agents. Important among the latter is the wind, which heaps the dry sands of the beach into dunes, thus insuring the stability of the beach as such above the water. A very considerable amount of sand is also blown into the lagoons which lie behind the off-shore beaches, thus materially aiding in the slow process of filling up those water bodies.

Outside the beaches and along the coast various marine currents are constantly at work distributing the sands which the waves and the undertow bring out from the beach or stir up from the bottom. These currents may be of tidal origin, set in motion by the daily ebb and flow of the great tidal wave, and would have their directions determined by the obliquity which the crest of the tidal wave[1] makes with the general direction of the coast line. Other tidal currents

[1] By *tidal wave* is here meant the broad wave of water which the attraction of the moon and other forces maintains upon the open ocean and draws after it as the earth turns upon its axis. The term should not be confused with the phenomenon popularly called a "tidal wave" which results from some volcanic explosion or seismic disturbance beneath the ocean and has nothing whatever to do with ordinary tidal phenomena.

with general off- and on-shore directions occur at the tidal inlets to the lagoons and sounds behind the beaches, where the inflowing and outflowing waters of the sounds have built bars and extensive shoals or tidal deltas.

The waves themselves, aided by the winds which drive them, set up the most important currents. As the waves run obliquely against a coast they set up a steady drifting of the water in the direction resultant from the direction of the coast and the direction in which the surges are moving. For example, if, as is the case on Maryland coasts, the heavy surges set up by a storm come rolling in from the east or northeast against a shore line whose general direction is southwest, the energy of those waves is partly expended in beating directly against the beaches, although a very considerable component turns along the shore in a southwesterly direction. In this way a southwest drift along shore is set up. Again, storms from the southeast, in a similar manner, set up a northeasterly drift or coast current.

These currents are well known to the fishermen and members of the Life Saving Service along our coasts. Their direction of flow may be detected by the drifting of wreckage during and after storms, and the average direction of drift during series of months and years is expressed in the general configurations of the beaches, capes, inlets and shoals. Along the Maryland and Virginia coast there seems to be an almost even balance between the two sets of currents. To the north, *i. e.* on the Maryland shores, the smooth beach shows but little by which to judge. The closing of an inlet into Sinepuxent Bay (see below, p. 83), and the recent opening of a shallow one to the south, across the beach into Chincoteague Bay, are in favor of a southerly current. So also is the general configuration of Assateague Island and its apex at Fishing Point, while the general direction of the shoals and bars off Cape Charles indicate that a decided current from the north brings down the sands which are drifting around the Cape into the mouth of Chesapeake Bay.

On the other hand, the position and direction of the banks and bars of the Chincoteague, Black Fish, Winter Quarter, Isle of Wight and Fenwick Shoals and the forms of the beaches on the east side of the Eastern Shore of Virginia point very decidedly towards the presence of a current setting from the south or the southwest.

### *Coastal Lagoons.*

Behind the low sandy beaches along the Atlantic coast of Maryland are imprisoned shallow lagoons somewhat similar to those of the New Jersey coast. These bays, though having different names in different parts, Sinepuxent, Isle of Wight and Chincoteague Bays, are nevertheless all one body of water. The width is very variable, ranging between half a mile at Ocean City to four or five miles at the wider portions. The shores of the lagoon are formed on the east by shallow marshes along the western edges of the outside sandy beaches, and on the west by the low, half-submerged topography of the mainland, somewhat modified by the salt marshes, which have attained considerable size at some points.

The floor of the lagoon is very shallow and flat, and largely composed of sand, which blows over from the dunes along the beaches, of mud and, near the western shore, of matted roots, which really form the foundation for the overlying sands.

The deepest portions of the bays are found along the western side, next to the mainland, and even in these spots the depth does not exceed seven or eight feet. Over most of the bay the depth is from one to three feet, so that the waters can be navigated only by boats of very shallow draught. The reason that the channel, as the zone of deepest water is called, is uniformly located so far towards one side, and that the western one, is, that the easterly storms, and indeed every brisk wind, blow quantities of sand from the dry dunes of the beach across into the bay. Thus a sandy shoal, now only one or two feet below the level of high water, has been built just in the lee of the barrier beach. Eight or ten rods in the width of this shoal have been so far built up, that it is now a brackish marsh overgrown with coarse salt grass, and much of it is firm enough to tread on without sinking. Beyond this naturally reclaimed portion the shallow sandy bottom is steadily encroaching year by year upon the formerly deeper waters of the bay. At the same time the marshy western shores of the lagoon are being slowly consumed by the attacks of the waves which arise in the shoal waters of the bay, although no accurate estimate of the rate of recession can be given.

The currents and the position of the water level in Sinepuxent and Isle of Wight bays are not influenced at all by the tides, and very little, if at all, in Chincoteague Bay, except in the immediate vicinity of Chincoteague Inlet. All the important currents are controlled entirely, both as to their directions and force, by the winds and configuration of the bay shores. When a brisk north or north-east breeze is blowing the waters are driven southward, thus setting up a current in that direction and tending to cause low water in the upper end of the bay, while a southerly wind may at another hour of the same day wholly change matters and heap up the waters at the north end of the bay.

The waters of these shallow lagoons do not communicate with the ocean except through Chincoteague Inlet and a small break in the long cordon of sandy beach that was recently made a few miles south of Ocean City during a severe storm. Up and down the whole length of the Maryland shore there are but these two inlets to the land-bound waters, one being very small and unimportant. This condition is not typical for such bays or lagoons as are found on the coasts of New Jersey and the Carolinas. It is more usual to find inlets interrupting the even stretches of sandy beach at several points, forming gates to the sounds similar to Barnegat Inlet of the New Jersey coast or Topsail Inlet of the Carolina coast. Such inlets, however, are of uncertain duration, and several along the Carolina shores are known to have been closed completely, as the result of the washing in of sand during great storms. Other inlets, formerly deep enough to admit sea-going vessels at low tide, are now so shallow that entrance is completely barred. It appears that one or two such inlets at one time cut across the long sandy reaches of Sinepuxent beach.

J. T. Ducatel[1] states in his Annual Report for 1835, that: "It is an interesting fact connected with the past and present condition of Sinepuxent sound that, since the closing up of some inlets admitting

[1] Ducatel, J. T., and Alexander, J. H., Rept. on the New Map of Maryland, 1835, p. 52.

the ocean into it, its waters having thus become comparatively fresh, the oysters and clams, by which they were formerly thickly inhabited, have died, leaving extensive beds of their exuviæ." The former abundance of these shell-fish in the sound is also evidenced by the Indian shell heaps found on Sinepuxent neck, proving that the Indians of the vicinity resorted to the sound for their supply of oysters. This change in the saltness of the water of the sound is an interesting illustration of the control exerted by geological conditions in changing the lives and habits of men. Prior to the storm, or series of storms, which closed the inlets, the thriving oyster beds attracted the aborigines and furnished them with a much prized article of food; now the nearly fresh waters of the same sound no longer support the finer grade of salt water oysters, and to obtain them we must search farther south in the vicinity of Chincoteague Island where the ocean waters still reach.

## SUBAËRIAL DIVISION.

### *Boundaries.*

The subaërial division of the Maryland Coastal Plain extends from the western shores of Chincoteague and Sinepuxent Bays to the western boundary of the province. It will be regarded as embracing the so-called "tidewater" section of the state with its many navigable streams and that old river valley, the Chesapeake Bay, which, from earliest times, has been the leading highway of traffic in Maryland.

### *General Topography.*

Passing from the submarine to the subaërial division of the Coastal Plain, there is no sudden change in general topographic features. The surface of an area newly arisen above the sea, where it had long been the seat of deposition, would naturally possess the predominant characteristics of the sea floor. One prominent feature is the broad, even plain, once the smooth or gently undulating sea bottom. The relatively new land surface of this division possesses this character in a very marked degree, and is typically illustrated by Plate VII, Fig. 2. Many portions of the Eastern Shore of Maryland are characterized by long interstream stretches of considerable breadth that are almost plane surfaces, and the same is true of several areas on the Western Shore in the peninsula of Southern Maryland. Taken as a whole, the Subaërial Division is quite as flat as the Submarine Division, although considerable depressions, particularly in its western portions, due to stream erosion, cause many interruptions in the continuity of the plain.

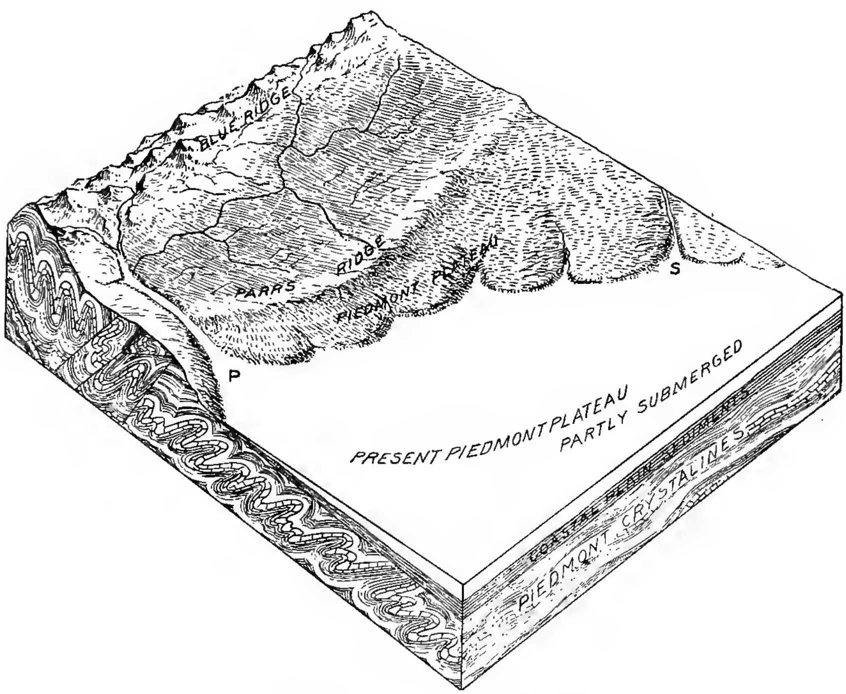



Fig. 11.—Piedmont Plateau partially submerged.

Another feature generally belonging to emerged marine plains, and characteristic of that portion of Maryland's Coastal Plain which falls under this class of land forms, is the gentle and uniform seaward inclination of the general surface. This is admirably shown by the hypsometric map forming Plate VI of Volume I, 1897, of the reports of the State Geological Survey. As may be seen from this map, the general slope of the Eastern and Western Shores of Maryland is towards the southeast, the rate of decline being about threc feet per mile for the counties of Southern Maryland and rarely more than one and a half feet per mile over the eastern counties of Kent, Queen Anne's, Caroline and Talbot.

### *Drainage Pattern.*

Besides the general features of the province and the gentle seaward slope of its surface, the drainage pattern, which is the direct product of these two factors combined with the general homogeneity of the strata, is characteristic and typical for the area. This stream pattern is irregularly branching or dendritic. The smaller streams in most cases make approximately a right angle with the general course of the larger streams, where they join the latter, but the larger waterways do not obey the laws which govern drainage development under the simple conditions of a Coastal Plain, although the courses of the main stream, it is true, are approximately parallel with one another and enter the bay or ocean at right angles to the shore line which they intersect. Most of the streams, however, depart from the type in that they do not traverse the width of the Coastal Plain's subaërial portion from the old land to the Atlantic, but generally flow from either side down into Chesapeake Bay. This abnormality of the streams will perhaps be more easily understood if the stages in the development of drainage on an emerging Coastal Plain are briefly reviewed.

### *General Drainage Development.*

Starting with the epoch when the western portion of the Coastal Plain began to appear above the sea, it is evident that, as the land rose and the waters receded eastward from their old bounds, the rivers flowing from the older land area or the Piedmont Plateau would gradually extend their courses across the new land, keeping their mouths at the new shore line. This advance of the lower courses of the old streams would keep pace with the retreat of the coast line, and the direction of the new lower courses would be determined both by the slope and the inequalities of the new surface over which they passed. In the normal course of events, therefore, these extended streams should enter the ocean by courses approximately at right angles to the general direction of the coast line, as shown in Fig. 12. This is to be more confidently looked for in the case of those streams whose volume and size would enable them to easily overcome the slight obstacles which the generally smooth surface of an emerged marine plain might offer to such a course. Such is the case with the Chattahoochee, the Tombigbee, the Savannah, the Santee, and num-

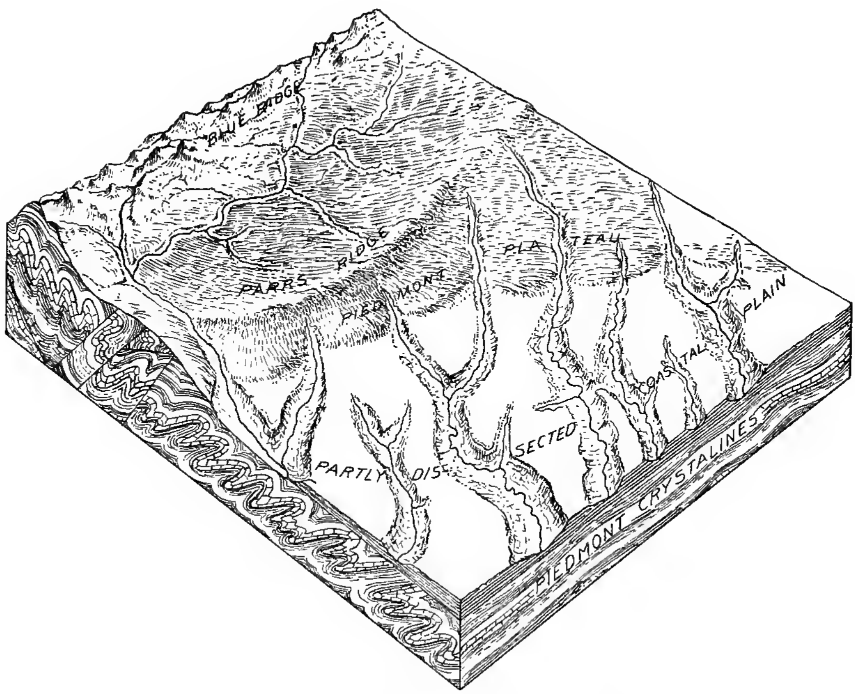



FIG. 12.—Piedmont Plateau and Coastal Plain elevated.

bers of others which cross the southern Coastal Plain from the old land to the sea. It is therefore surprising to find that large, powerful rivers, such as the Potomac, the Susquehanna and the Delaware, which have successfully crossed many resistant strata in the Appalachian district, turn aside on reaching the incoherent beds of the Coastal Plain and pursue such roundabout routes before they finally reach the Atlantic.

While the streams of the old land are thus actively extending their courses and reducing their channels to a suitable grade, another class of streams have come into existence. The rain which falls upon the surface of the newly-born land is partly drained into the extended lower courses of the preëxisting rivers, but it also happens that a large share of the drainage is effected by streams which originate upon the Coastal Plain itself independently of the extended rivers. These streams, which arise independently of former drainage lines of any sort, are guided in their development only by the character of the strata and the initial inequalities, large or small, which they find on the surface of the new land. As the general inclination of the surface is seaward, and they are acting almost wholly under the influence of gravity, their courses are taken as nearly as possible along the lines of steepest slope, generally at right angles to the coast line.

If the land continues to rise these new streams also will extend their lower courses to keep pace with the receding shore line. At the same time their headwaters are being extended by the gnawing back of the ravines which characterize stream heads and by the development of new ravines. These new ravines start upon the side slopes of the old ones, and as there is no important variation in the amount of resistance offered by the various strata, whereby any control could be exerted upon the direction of growth of the new ravines from which they start, all have equal chances for development. A ravine once started tends to keep on in the same direction, as may be observed in the case of the small ravines and gullies developing along bare hillsides. The result of this mode of development is the growth of a more or less intricately and irregularly but systematically ramified drainage system of dendritic pattern, which has come to be recognized as typical for the drainage developed upon newly exposed plains of subaqueous origin. Smaller streams of the same type may also develop in regions whose main drainage lines are under control of other factors, such as tilting or folding. In these cases the subordinate or tributary streams only will belong to the type under consideration. This is an important fact, as it will appear that to this second category belong the majority of the streams of the Coastal Plain in Maryland. This general stream pattern has been designated by McGee [1] as *autogenous*.

During the earliest stages in the drainage development of an emergent coastal plain, small lakes and swamps may dot the surface of the new land in greater or lesser numbers. They would arise from the accumulation of rain-water in the original inequalities of the surface. Such inequalities on the sea bottom are produced by the actions of waves and currents which do not always distribute sediments in a perfectly even manner. This is very well shown by the character of the sea floor along the present Maryland coast. The lakes or swamps, due to accumulation of water in such hollows, should disappear early in the course of drainage development. Their outlets generally admit of rapid cutting down, so that the waters are soon drained off. Thus lakes of this origin, characterizing only the earliest or *Infantile* to *Adolescent* stages in topographic development, when present, give a clue to the topographic age of the area.

The ideal scheme of Coastal Plain drainage as outlined above is interrupted by the southwestward prolongation of the Susquehanna river in the expanse of Chesapeake Bay, which divides the Subaërial Section into the Eastern Shore and the Western Shore of Southern Maryland.

## THE EASTERN SHORE.

The Eastern Shore of Maryland occupies a large part of the peninsular Coastal Plain between Delaware Bay, the Atlantic Ocean and Chesapeake Bay. This topographic subprovince also includes most of Delaware and the Eastern Shore of Virginia.

### *Relief.*

The peninsula has but slight altitude, rarely reaching a maximum elevation of one hundred feet even in the higher northern counties, and declining gradually southwards to a mean elevation of about twenty-five feet in Somerset and Worcester counties. Besides the broad open valleys of the larger streams and the flat interstream

[1] McGee, W J, U. S. Geol. Surv., Eighth Ann. Rept., 1885-86, pp. 561 et seq.

areas, the only topographic feature of prime importance is the broad height of land which forms the divide between the eastward and westward flowing streams. At this point it is enough to indicate that its distance from the Atlantic or from Delaware Bay rarely exceeds fifteen or twenty miles, while it generally lies from thirty to forty miles east of the eastern shore of Chesapeake Bay and just north of Berlin, Maryland, is sixty miles distant. The high land extends south-southeast from Elk river, keeping approximately parallel to the eastern shore of the peninsula as far as the headwaters of the Pocomoke river. It then turns to the south-southwest, following the Atlantic coast line in a sympathetic curve down the lower portion of the Eastern Shore of Virginia, gradually decreasing in elevation until it merges into the low-lying lands north of Cape Charles.

*Stream Characteristics.*

The Eastern Shore is on the average fairly well supplied with streams, the majority of which drain southwestward into the Chesapeake. All the large streams, following more or less tortuous courses, flow into the Bay, and most of the smaller streams have courses roughly parallel to the larger ones. Only small streams, generally insignificant in size and comparatively few in number, drain eastward into the lagoons lying behind the off-shore beaches and bars of the Atlantic coast.

All the streams fall into one or the other of two classes. They either lie wholly upon the general surface of the country, are small in volume, not navigable, except where dammed, and do not reach directly to tidewater, or they reach tidewater and the larger ones are navigable at least by small boats for some portion of their length. The streams belonging to the first class are characterized by broad, shallow valleys, with very gentle side slopes, which are not seamed by rill-channels, but present smooth, rounded or even plane contours. Generally there is some alluvium collected along the stream channels, but as a topographic feature these flood-plains are usually difficult to distinguish from the mild side slopes of the valleys. In the northern portion of the Eastern Shore peninsula, where the general altitude is highest, the streams have more sharply defined valleys, and are, in general, more actively engaged in working over the materials of their flood-plains. Contrasted with this section, are the streams of the inter-estuarine areas in the southern counties. There one may travel for miles and never cross a well-marked channel. Where the forests have been allowed to remain, they have so far prevented evaporation that the swamps which formed in original surface inequalities retain a considerable amount of moisture, even through the hot summer months, and sometimes little rivulets may be found in close proximity to these forested areas. As a rule, however, the configuration of the surface betrays no sign of stream sculpture, but seems to have received its outlines wholly from the waves and currents of the ocean during its last period of submergence. It is in the middle counties—Talbot, Caroline and Dorchester—that the streams approach more nearly the typical inland drainage of a recently emerged marine plain. In these counties the stream characters correspond closely to the general description given above.

The streams whose lower courses merge into tidal estuaries belong to the second class of Eastern Shore Coastal Plain streams. The headwaters of nearly all the members of this class belong to the first class of streams, and present the characters which have been described. The transition in these streams from the shallow alluvium-lined valleys of the above-tide district to the free and open estuarine division is not a sudden one. Between the two extremes lies a stretch of river whose waters ebb and flow with the tide, but whose steep banks are deeply fringed by reed-covered marshes. This transition is most clearly and beautifully illustrated by the Choptank river, which may be taken as the type. The same features are shown almost equally well by the Nanticoke, the Wicomico, and the Chester rivers.

The lower course of the Choptank is an open bay about six miles wide in its broadest part, so that in spite of the comparatively shallow waters (off Cook's Point there is a maximum depth of ten and one-quarter fathoms) strong winds or sudden storms in summer always set a heavy sea running. The shores are low, rarely rising twenty feet above tide, and intricately dissected by small tidewater creeks, particularly along the peninsular area between the Choptank and Eastern Bay. The banks facing the channel do not slope down gently to the shore, except in those cases where the land stands lowest and is in a protected bay. Usually they form sharply-cut cliffs of varying height. These cliffs, fashioned by the waves which often arise on the river, are best developed along the exposed stretches of shore, and are in every instance accompanied by some form of spit or bar stretching to leeward, and built of the waste cut away by the waves. Already in this lower course of the river, the small creeks emptying into it are found to be shoaling and silting up their channels, as a result of the sand-bars and beaches which obstruct their mouths. Proceeding up the river, however, the marshlands, which have been confined to creeks and lagoons below, begin to encroach on the open waters of the channel. The sharp points, unlike their congeners downstream, do not have off-shore extensions in the shape of sandy shoals or spits, but have developed marshy accumulations of sand and alluvium firmly woven together and held by a mass of matted grass roots. For a short distance these marshes are confined to the stream mouths, and the points, while having intermediate stretches along the shore, are undercut, forming cliffs. These cliffs can often be traced along behind the marsh-formed outlines of the points and bays. Above Secretary creek the marshes increase in area so greatly that the bounds of the channel are formed almost wholly of those accumulations. The tortuous stream grows narrower as the marshes widen, and swings in broad meanders, sometimes cutting directly against the steep banks of the stream, when a strong bend carries the current sharply to one side or the other.

Back of the marshy ground the banks of the river appear as steep cliffs, which are now well wooded, and thus protect the banks from the attacks of the rain and the wind. These steep wooded banks present a decided contrast to the generally less precipitous slopes which border the small tidewater confluents of the Choptank, and they clearly form sudden interruptions in the broad, gently rolling surface of the interstream areas. The boundaries between the firm land of the Coastal Plain and the tidal marshes, as expressed topographically by these low bluffs, are clearly designated on the U. S. Coast and Geodetic Survey Chart No. 135. This chart conveniently sums up for general study the tidewater details of the river system, and shows even better than one can see the facts on the ground, the gradual encroachment of the marshes and the line of low bluffs behind them. It is very clear from this map that the original banks of the river, up to the head of navigation and beyond, are represented by these marsh-bound cliffs. Apparently the earlier channel, which the river followed before it had built the marshy flood-plains, was much more direct than it is to-day. Some allowance, however, must be made for the straightening of the banks under the action of the waves in earlier times, such as is now going on farther down-stream. At the present time, also, there is some straightening done by the cutting of the stream where its channel is turned against the higher bluffs at the apex of some meander.

Above tidewater a marked change comes over the valley. Instead of strong tidal currents, which by their scour keep open a narrow pathway, the channel is occupied by a small stream, which is unable to carry away all the waste washed into it from the valley slopes. These slopes, also, while maintaining their steep faces for a short distance, rapidly give way to the milder slopes and open valleys of the interior. The flood-plain, which characterizes the stream in its non-tidal portion, is clearly continuous with the growing marshes of the tidewater district.

On comparing the other large streams of the Eastern Shore with the Choptank, they are found to depart but slightly from the characteristics of that stream. What variations occur, relate chiefly to the shores of the estuarine portion, and are discussed below under the head of Shore Features.

The streams flowing eastward into the coastal lagoons of the Atlantic shore have already been briefly touched upon. They are, in Maryland, small and insignificant runs, flowing over marshy bottomlands. The largest is St. Martin's river, emptying into Isle of Wight Bay, and next in size is Trappe creek, which flows southeastward from Trappe, near Berlin. Although so insignificant in Maryland, this Atlantic drainage attains a somewhat greater, although still very moderate, development in Delaware, where it numbers among its principal streams Indian river, Broad Kill, Mispillion creek, Motherkill or Murderkill creek, Appoquinimink creek and Christiania creek. The topography along the lagoons of Maryland and behind the off-shore beaches on Delaware Bay clearly shows that these creeks, even the smaller ones, belong to the class of streams known as "drowned." That is to say, after having established themselves upon the new land surface, and cut out characteristic valleys, a slight subsidence has allowed the sea waters to penetrate inland, overflowing and drowning the lowest portions of their valleys. The larger streams of St. Martin's river and Indian river have, with the Pocomoke and Nanticoke rivers, common sources in the Great Cypress Swamp which covers such a large area in Sussex county, Delaware and Wicomico county, Maryland.

This swamp is particularly interesting because of its position on the great Atlantic-Chesapeake divide discussed below. It has been pointed out that one of the characteristic features of the ideal drainage of a newly emerged Coastal Plain is the formation of lakes, swamps, morasses, etc., in the original inequalities of the new surface. There are along the Atlantic seaboard several examples of such swamps, and particularly are they found in Florida, Virginia, Maryland and New Jersey, including the Everglades, the Great Dismal Swamp of Carolina-Virginia, the Great Cypress Swamp of Maryland-Delaware, and numerous small swampy districts along the Atlantic-Delaware river divide of the Coastal Plain in New Jersey. In all these cases there are two reasons why the swampy districts have not been drained. First, they are formed in inequalities produced by a submergence which took place in very recent geologic time, namely, the Pleistocene epoch. These districts seem to have been the last to come above the sea, even at that late date, so that there has been but little time for streams to do much active cutting. Moreover, it is to be noted that these swamps are located chiefly along main divides, suggesting that the streams which sprang up during the first period of post-Pleistocene emergence were able to drain swamps which were located nearer the shore line, but have not as yet found time or strength to draw off the waters confined by the inequalities of the main divides.

### *Atlantic-Chesapeake Divide.*

The peculiarly swampy character of this divide and its unsymmetrical location on the peninsula between the Atlantic and Chesapeake Bay are facts which distinguish it, when compared with the more usual characters of stream divides, and the laws which control their development.

It has been pointed out, in discussing the origin of the Coastal Plain province, that streams whose courses were extended across its subaërial portion or originated thereon would normally flow eastward and southeastward into the Atlantic. Thus the divides crossing the Coastal Plain would have been parallel to the streams and approximately at right angles to the shore line. How then can the present arrangement of drainage lines on the Eastern Shore be accounted for? In studying the development of stream divides it has been found to be a general rule that when the streams on one side of a watershed have a greater development than their opponents on the other side, their superiority may be traced to one of two causes. Either some original characters of the country gave to one system long courses and to the other short ones, or some features in the district subsequently revealed in the course of continued development have combined to aid one set of streams, while not offering equal advantages to the others.

There is no apparent reason for the unsymmetrical location of the divide in question, when the normal development of the Coastal Plain is examined for an original cause. The whole history of the Coastal Plain, so far as it is recorded in its earlier sedimentary deposits, would go to show that the streams ought not to be abnormal in any particular. Neither can there be found any traces of factors which, appearing after the streams had begun to develop, would be able to influence them in such a marked manner. A common factor of this latter class which in many parts of the country has played an important rôle is a heavy or very resistant stratum of rock. Such a stratum, by retarding the development of the streams compelled to flow over it, gives the other streams, not so hindered, an opportunity to advance their headwaters and to reduce their channels more rapidly to a gentle slope. But no stratum of sufficiently contrasted resistance to produce such an effect can be found in the series of Coastal Plain strata within the boundaries of Maryland. If the indurated clays and sands of the Lafayette Formation be appealed to as sufficiently resistant to have such an effect on the streams the results produced would be just the opposite of those observed. The westward-flowing streams would first have encountered the opposition of the eastward dipping beds of the Lafayette, while the eastward-flowing streams of the Atlantic, having their courses down the dip, would have been last influenced by such opposition. The result then would have been that the Atlantic drainage would have developed at the expense of the Chesapeake streams, and the divide would now stand nearer the bay than the ocean.

Again, in a district of comparatively uniform and homogeneous lithologic structure such as the Coastal Plain, it might easily happen that one portion, receiving a heavier average rainfall, should therefore develop a stronger drainage system. The maps of average Annual Precipitation in Maryland and Delaware, published in the report of the Maryland State Weather Service for 1892-3, show the heavier rainfall to have occurred within the catchment basins of the Choptank streams, while the maps for 1894-5 show a slightly greater fall for the Atlantic streams in the same latitude. There are no strongly marked topographic features of the Eastern Shore which exert any control over the distribution of rain, and it is probably fair to conclude that the average of a number of years would show that there is a pretty even and equable distribution of rain to either district.

### *Shore Lines.*

The most striking feature of the Eastern Shore, next to its extreme flatness, is the very intricate character of its western shore line. At first sight the meandering outlines appear to be a maze of creeks and coves without plan or system, and certainly the stranger, who tries to find his way about the multitude of creeks along Kent Island and Eastern Bay at the mouth of St. Michael's river or in Bay Hundred at the entrance to the Choptank, would soon become confused by the great number of closely similar creeks and minor estuaries which are found there. These intricacies all work out very simply, however, by tracing out certain lines which may be found more or less clearly marked in nearly every cove and bay.

If, on one of the U. S. Coast and Geodetic Survey Charts of Chesapeake Bay, lines be drawn along the channels of the principal streamways, a pattern will be produced resembling so many bare trees, very crooked as to their trunks, and stripped of all except the largest limbs. The roots of these river trees lie in Chesapeake Bay, and their tops, merging into the surface streams of the province, lie against the great divide.[1] Tracing out the channels of all the little tide-creeks and bays, it will be found that many of the channel lines join or branch from the main stem and major branches, thus forming the subordinate branches and twigs of the "trees." Several smaller independent systems, such as the Little Choptank, Eastern Bay and St. Michael's rivers, which spring directly from Chesapeake Bay, will also develop.

If now these "trees" be compared with the branching patterns of most streams, for example, of such a river as the Patapsco of the Piedmont Plateau or the Patuxent of the Piedmont and western Coastal Plain, a striking similarity in the systematic irregularity of the branching at once appears. From such a comparison it is but a step to the conclusion that running streams of fresh water once carved out the channels which are now filled with the brackish waters of Chesapeake or Isle of Wight Bays. An elevation of one hundred feet would be sufficient to convert all these irregularities of coast line into a corresponding multitude of larger and smaller creeks which would empty into a great tidal river along the main channel of Chesapeake Bay. A depression of less than half this amount would convert all the rivers of Dorchester, Somerset, Wicomico and Worcester counties into such tidal creeks as are now found along their shores, and to a less extent would affect in a similar way the present streams of the more northern counties. Chesapeake Bay and its

[1] See Russell, I. C., "Rivers of North America," Fig. 22, p. 219.

tributary bays and rivers thus belong to that great class of streams called *drowned rivers*, and the coastal topography of the whole Coastal Plain of Maryland is for a similar reason to be classed as *drowned topography*.

Drowned topography and drowned rivers are not peculiar to Maryland, however, nor even to the Coastal Plain, although they are excellently illustrated in these districts. The numerous islands and deeply land-locked harbors along the New England coast, particularly in the state of Maine, afford beautiful examples of the same kind of coastal features, while the beautiful friths of Scotland and the famous fjords of Scandinavia and Finland are world-renowned examples of this class of land forms.

Since the drowning of the streams, the resultant expansion of the water areas in the valleys thus affected, and the introduction of tidal currents, have brought new forces into action which influence the development of shore topography along the streams. In describing the lower course of the Choptank, mention has been made of the wave-cut cliffs and wave- and tide-built bars and spits, which now distinguish the estuarine portions of that stream.

All these features are developed to a greater or lesser extent in the other rivers. The best development of wave-cut cliffs is found along the Sassafras and Chester rivers, where wide expanse of water is combined with high banks. The waves generated by the severe southeast and southwest storms, although raised in comparatively shallow waters, are forceful enough to undercut and bring down great masses of the indurated fossiliferous sands and marls. These blocks lie quietly on the shoal beaches during the numerous small storms of summer, but in winter are rapidly broken up and distributed along the shores. As a result of this continual supply of new material from neighboring cliffs, waves are building sand bars across the mouths of the smaller creeks, and as a result of this damming they are gradually filling up.

The tide flowing in and out of the rivers twice a day is also a factor and an important one in fashioning the outline of the river's shores. Several shore forms in the Choptank have been described and attributed mainly to wave work. The side-currents or eddies set up between the shore and the main tidal current in the channel generally play an important and sometimes a controlling part in the building of the spits and bars which characterize the shores. The manner in which these tidal eddies work has been recently worked out by Dr. F. P. Gulliver[1] for a much larger estuary on the coast of the state of Washington, and Fig. 13 is designed to illustrate the arrangement of such eddies during flood tide. No special studies have yet been made of the many admirable shore features which the rivers of the Coastal Plain exhibit, but while working on the areal geology of the Eastern Shore I was able to note that in at least one case eddies

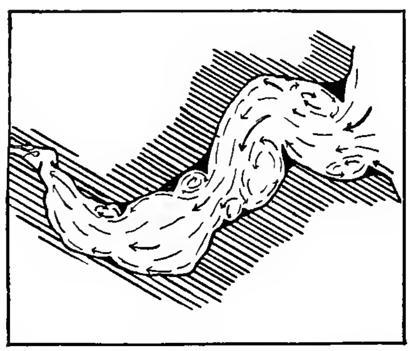


FIG. 13.—Scheme of Flood-tide Eddies in an Estuary (after Gulliver).

set up by the tide had influenced the growth of a cusp on the Sassafras, and it is very probable that tidal currents have also been influential in determining the growth of two sandy points on the Choptank.

The example in the Sassafras river is found at a point on the south bank of the river a short distance below Ordinary Point, which is itself probably, in part at least, the result of similar eddies. One day while endeavoring to tack down stream my companion and I found that we could make very little headway as we approached the south shore at this point, although when out in midchannel the strong ebb tide helped us along very nicely. On looking over the

[1] Gulliver, F. P., Bull. Geol. Soc. Amer., vol. vii, pp. 411-41, Fig. 7.

side of the boat I saw that the waving eel-grass which grew in the shallow water near the shore was turned up-stream by a steady current of some strength. Evidently here there was a back-set eddy given off by the channel current, and conforming in its course to the smooth curve of the sand and gravel beach whose outline it had been instrumental in determining.

On the same river the long sandy spit known as Ordinary Point has been built up by the combined forces of tidal currents and the southwest winds, which set up strong waves, particularly in the broader portions of the lower river. The waves beating against the sandy cliffs on the northern bank of the river have washed out great quantities of sand, which the shore currents have carried up-stream, until, being deflected out towards the channel by a low point of land, they were there opposed by the tidal currents and forced to drop the sand which they carried. The tide acting regularly twice a day overbalances the less regular action of the strong waves, and has now stopped the further growth of the bar across the channel, by turning the tip down-stream, so that its further growth is opposed by the very waves which serve to build the bar outwards.

Besides these constructive and destructive changes which are taking place within the smaller estuaries, the islands at the mouths of the rivers seem to be gradually wearing away. The low swampy islands which characterize the Chesapeake border of the Eastern Shore are reported to have been firm, dry lands twenty-five years ago. Certainly now many fine trees which once flourished on them are being killed by the salt water penetrating to their roots. In many places, for example along the exposed portion of Kent Island, it is found that marshes formerly protected by and formed behind sandy beaches are now exposed directly to the beat of the waves and are being rapidly cut away, leaving a bench of soggy and matted roots about two feet below the mean tide level. Many years ago Ducatel[1] reported that the mouth of the estuarine portion of Pocomoke river and sound were filling so steadily with detritus and fine mud that it was not practicable to keep a ship-channel open there as an approach

[1] Ducatel, J. T., and Alexander, J. H., Report on the New Map of Maryland, 1835, p. 49.

to a ship canal. It is also significant that the upper portion of the Wicomico river must be annually dredged out and the banks held back by posts and planking for the distance of a mile or so below Salisbury in order that the ship-channel may be kept free from the considerable amount of sand and mud which washes down from the surrounding banks.

These phenomena of washing away in certain portions seem to be contradictory, for the filling up of the streams does not occur at points where it can be related to the washing and wasting of the banks and cliffs before the attack of the waves. The washing away of the cliffs is chiefly confined to the districts in the vicinity and along the shores of Chesapeake Bay, except for the great flats which are growing in Pocomoke sound, while the filling is going on near the heads of navigation of the tidal streams. The rapid cutting which is going on along the western shore of the Chesapeake is interpreted by McGee[1] as an indication that the Coastal Plain is now subsiding, since only by steady subsidence can such continued wasting of the cliffs without contemporaneous shoaling of the adjacent shallow waters be accounted for. The steady filling in of the Eastern Shore streams of the tidewater province must either indicate a tilting, whereby the eastern portion of the Coastal Plain is being slowly raised and the bay portion depressed, or else the phenomenon directly contradicts the above conclusion, and the fact that Chesapeake Bay does not shallow more rapidly is to be explained by supposing that the original depth of the bay was greater than has heretofore been considered as probable. A consideration of the estuaries on the peninsula of Southern Maryland may offer a solution to this problem.

### THE WESTERN SHORE.

The streams of that portion of the subaërial Coastal Plain which forms the peninsula of Southern Maryland or the Western Shore all belong to Chesapeake Bay drainage. There are but two or three large rivers which can be properly regarded as coming within the boundaries of this section, namely, the Potomac, the Patuxent and

[1] McGee, W. J., U. S. Geol. Survey, Seventh Ann. Rept., p. 618.

possibly the Susquehanna. All three of these streams have very considerable portions of their courses located upon the crystalline and the non-metamorphic formations of Western and Central Maryland or Pennsylvania, while only the lower portions of their courses cross the western portion of the Coastal Plain. All the other streams of the area rise within the boundaries of the Coastal Plain, so that their courses lie wholly within the province, and their origin upon the surface of the plain is obvious. The history of the three streams first mentioned is less evident. The Potomac and the Susquehanna which head far back in the Alleghanies and assumed the upper portion of their courses long before the Lafayette (Pliocene) submergence, undoubtedly belong to that class of streams already described which extended their lower courses seaward from the old land across the emerging plain. The Patuxent, judging from the present geological map of Maryland, would also seem to belong to this class of extended rivers. It is believed, however, from studies of the neighboring and related streams of the Piedmont Plateau, as well the features of its headwaters, that this stream, together with the Gunpowder and several others, originated on a former western extension of the Coastal Plain, all sedimentary records of which have been removed by subsequent erosion.

The streams of the Western Shore when compared with those of the Eastern Shore present considerable similarity in general features such as the drainage pattern, drowning and terracing. In several respects these features are more sharply accentuated than in the Eastern Shore streams. The reason for this seems to be the greater amount of elevation which this section underwent at the time of the post-Lafayette emergence whereby the streams were able to cut deeper valleys which now give high-banked estuaries with more marked terraces.

*Stream Characters.*

As soon as the "extended" streams of the Western Shore cross the western boundary of the Coastal Plain, *i. e.* the Fall Line, their valleys undergo a sudden change in character. From the narrow, steep-sided gorges which characterize the streams of the Piedmont, the valleys change to open meadows bounded first by one or two broad terraces thirty or forty feet above the meandering channel and farther off by low, mild hill-slopes. These terraces can sometimes be traced up the streams westward from the Fall Line and are then found to merge into probably contemporaneous terraces, described later, which characterize a number of the Piedmont streams. Of the streams which present good illustrations of these confluent terraces may be particularly mentioned the *extended* Potomac, Anacostia river or the Eastern Branch and the Patuxent.

Proceeding down-stream from the vicinity of the Fall Line the stream banks become higher and slightly steeper, the flood-plains do not increase much in size, and the terraces appear to stand higher above the streams. At the same time the small side-streams trench somewhat into the terraces and their own upper courses cut deep narrow ravine-like valleys whose lower portions are somewhat leveled by an extension into them of a terrace plain. The characters of the down-stream terraces and side ravines are very well illustrated along the Patuxent to the east of Upper Marlboro' and near Princess Anne in Prince George's county. At these points, however, the river already begins to be influenced by the tides and thus comes almost within the estuarine zone.

Along this lower fluviatile portion the terraces stand generally in two series, as they do in the upper portions. The lower series has an average elevation of five feet above the present flood-plain, and its width varies from one hundred yards to half a mile. It is composed of fine gravels, quartz sands and a small amount of clay and loam. The upper series stands forty or fifty feet above the lower and is built of coarser gravels and cobbles. Near Princess Anne a gully in this upper terrace clearly shows that it is in part the result of cutting, in part formed by the deposition of gravels.

Both sets of terraces have been trenched by the small side-streams as they cut their way down to the present channel-grade of the main drainage. These streams pursue direct courses across the upper terrace, however, while their steep-sided trenches meander through the lower terrace in a manner which indicates that previous to cutting of the present trenches they flowed for a time under flood-plain conditions. Such facts aid in picturing the conditions under which the streams have worked and give a clue to the relative variations in the rapidity of rise of the land after its Pleistocene depression, for these terraces represent stages in the fluviatile phase of Pleistocene deposition. The somewhat direct courses of the side-streams across the upper terrace indicate a rapid rise to some height which did not permit flood-plain conditions to arise. Having thus obtained an elevation of perhaps forty feet, the land remained quiet while the lower and broader terraces slowly formed. Finally, the land again rose, very slowly at first, so that the streams for a short time crossed extensive sand-flats just above the level of the water; then more rapidly, so that the runs trenched the meandering courses which they had been forced to assume during the short delay just preceding.

### *Drainage Plan.*

On comparing the drainage patterns of the Eastern Shore and the Western Shore no fundamental differences are to be observed. The streams of the Western are generally shorter than those of the Eastern Shore and are of steeper slope, but the method of branching is the same and the streams belong to the same class, that is, they are autogenous. Indeed, these streams, though smaller, have, on account of their sharper cutting into the higher land of the Western Shore, developed even more typical autogenetic drainage than the low-lying and weaker streams of the east. Thus the branching of the headwaters of the Wicomico river in Charles county or of the Piscataway creek in Prince George's county present admirable examples of autogenous development. This type of drainage is also represented in Fig. 14.

### *Divides.*

The most striking feature of the drainage of Southern Maryland is the location of the second-order stream divides. The Hypsometric Map of Maryland[1] expresses very well the unsymmetrical location of these divides, which always stand nearer the northern than the southern member of any two of the larger streams. Thus the streams of St.

[1] Md. Geol. Survey Reports, vol. i, plate vi, p. 142.

FIG. 14.—Unsymmetrical Divide between Potomac and Patuxent Drainage, near Leonardtown, St. Mary's County. (From Nomini Sheet, U. S. G. S.)

Mary's county, which flow southward into the Potomac are about three times as long as those which empty into the Patuxent. Similarly it is to be observed of the Calvert county streams that those flowing southwestward to the Patuxent predominate over those which drain eastward into the bay. This characteristic has already been recognized as a typical feature of the location of the divides of the eastern division of the subaërial Coastal Plain. It is a very interesting and remarkable coincidence that here in a region of more strongly marked relief and of more active streams is found a drainage system possessing the same unsymmetrically located divides which mark the sluggish drainage of the Eastern Shore. What makes the coincidence even more striking is the fact that the short steep streams lie to the east of the divides in both cases, while the longer, flatter streams are on the west slopes. These facts suggest very strongly that there may be some intimate and causal relation between the location of the divides on the Eastern and Western Shores.

If the divides and streams are studied on the small-scale Hypsometric map of Maryland a number of instances may be found which seem to suggest a simple explanation for the locations of the divides of Southern Maryland. In one case, that of Lyon's creek in Calvert county, the headwaters of the stream start with a southeastward course, but after flowing for two or three miles in this direction, make a sharp turn at right angles and flow off southwestward to the Patuxent. At the point where the creek makes the sharp bend a small stream heads and flows eastward into Herring Bay on the Chesapeake. Again in Charles county, southeast of Bryantown, the headwaters of a stream which empties into the Wicomico river start with a northeastward course, after a mile, sharply turn southeastward and again soon turn sharply southwestward. Near where this stream bends heads a small stream which joins the Patuxent just above Benedict, having taken a northeast course seemingly in direct continuation of the upper part of the preceding stream. These cases suggest that there has been some capturing by southeastward flowing streams and corresponding decapitation of westward and northeastward flowing streams. The large scale maps of the U. S. Geological Survey (see

Fig. 1.—TRIBUTARY OF THE CHOPTANK, NEAR QUEENSTOWN.

Fig. 2.—SEVERN RIVER, NEAR ROUND BAY.

Fig. 14) do not support this conclusion by detailed evidence. They do show, however, that the intricately branching headwaters of the southwestward flowing streams have pushed their weaker opponents very far to the northeast and have developed more intricate and extensive drainage systems than the latter.

Another factor which must be considered in any attempt to explain the unsymmetrical divides in Calvert county is the retreat of the cliffs along the western shore of the Bay. On comparing Plate VI, Fig. 2, with Plate VI, Fig. 1, there is seen to be a marked difference between the relief of the eastern and the western shores of Chesapeake Bay. The eastern shores are low and flat, while the western banks present picturesque cliffs such as those near Cove Point, shown in Plate II. This decided contrast is due chiefly to the fact that the Western Shore was originally elevated to a greater height than was the Eastern Shore. This initial difference, however, has been accentuated by more recent developments. The great storm winds on the Bay come from the northeast or the southeast, while the storms from the west are less severe and of shorter duration. Consequently the western shores are exposed to the severer storms and must withstand long-continued attacks of the larger storm waves. The result is that the bay shore of Calvert county, which from the configuration of the Bay is the coast exposed to the longest sweep of easterly winds, has been steadily undercut and worn back by the waves until the cliffs thus produced occupy a position several hundred yards west of the shore line which bounded the Bay in earlier times. The rate at which this recession has been going on is not known at present, but the members of the Coastal Plain Division of the Maryland Geological Survey have instituted a series of observations and measurements which in the future will yield some interesting results on this subject.

The fact of the recession of the cliffs is well established. In the course of the retreat the plane of the cliff face cuts across the topography of districts which formerly lay some distance back from the shore. The lower courses of many streams have been entirely removed, and their valleys which once descended to the bay level in the usual fashion now appear as notches in the crest line of the cliff. These notches are very beautifully shown in the view represented by Plate II. Again, a shallow bench of clay is found to extend out under the water from the present foot of the cliffs to a distance of one-third or half of a mile beyond which the water rapidly deepens. This bench is undoubtedly the planed-off stump left by the waves as they cut their way landward, pushing the cliffs before them. The result of this westward migration of the Cove Point cliffs has been to shorten very materially the length of the streams flowing down the present eastern slope of the Calvert county divide, and the appearance is thus produced of an encroachment upon the headwaters of these curtailed streams by the longer streams of the western slope. The unsymmetrical location of the divide in Calvert county is, therefore, in part at least, only apparent. Even if shore recession were an adequate explanation for the lack of symmetry of the Calvert county streams the same would not apply to the streams lying between the Potomac and the Patuxent. In this case the shorter streams which flow into the Patuxent have not lost as much of their lower courses by wave erosion as have the Calvert county streams, yet the lack of symmetry is just as marked as in the latter case.

*Estuaries.*

As the streams come more and more under the influence of the tides their banks gradually recede and the waves are found to have destroyed considerable portions of the Columbia terraces. Thus passing to the estuarine portion proper, high, steep wave-cut cliffs replace the sloping banks, and sandy beaches or wave-fashioned contours appear in the stead of sandy terraces. The broader valleys which the streams of this subdivision carved out, produced broader estuaries than those of the Eastern Shore when the subsidence took place whereby the streams were drowned. Hence the shore features along the Potomac and the Patuxent are those of stronger waves and tides and the variety of forms is greater.

Besides spits and barrier-bars or beaches, such as have been described from the Eastern Shore streams, there have also been formed along these shores V-bars, cusps, hooks, etc., which in many cases are worth studying because of the economic importance which they bear. For example, on the Potomac a lighthouse has been erected on the apex of the sawtooth-shaped V-bar which forms Piney Point. The sharper, shorter curve of the tooth is formed by the wide beach on the southeast or down-stream side, while the gentler back slope of the tooth consists of a long, gently curving, narrow beach which appears to be sometimes breached by the greater storm waves. The down-stream curve of the point, as well as the greater thickness of the down-stream beach, suggests that the growth of the point has been chiefly directed down-stream. For some miles above Piney Point there are long, smoothly curving beaches which bridge over the mouths of Flood and Herring creeks by means of low sandy bars, and thus give continuous and even sweeps of shore contours. These features are indicative of moderate and steady currents which sweep along the foot of the low cliffs and the barrier bars carrying sands southeastward to drop them off the point of the cusp. The shorter and more sharply-curving beach forming the southeast side of the point has been built by a weaker or less constant current which, flowing at right angles to the course of the first current, has carried the material brought by the latter around the point and down the short beach. These currents are the joint products of winds and tides, but the latter being regular and periodic in their action, are the controlling factors and have given the major characters to the estuarine shores.

Of a different type from the Piney Point bar is the formation of Point Lookout at the mouth of the Potomac. Piney Point was built by tidal currents which, for some reason perhaps resulting from initial inequalities in the shore line, set up eddies in whose triangle of confluence deadwater permitted bar-building. At Point Lookout the southerly drift along the bay shore set up by the prevailing northeast storm winds of the Chesapeake has built sand bars and beaches across Deep Creek into its neighbor, Tanner creek, and continued to grow southeastward until opposed by a current which sets along the curved beach and bar of Cornfield Harbor. This Cornfield Harbor current has built bars and beaches across Point Lookout and Potter creeks, and the growth of these northwestward indicates that the current here runs in the same direction for the longer period, although it is possible that reversals in its direction sometimes occur. A very brief examination of the eastern beach of Point Lookout reveals the fact that its method of growth has been at times gradual and again more rapid. During most of the time the minor storms and waves bring sands along the shore to be deposited as a long, evenly-sloping beach such as is forming to-day. Sometimes, however, great storms have arisen and their strong winds have raised waves so large that they broke some distance out from the beach then existing. Thus a second beach was built up by the waves although several rods out from shore, and when the storm subsided the every-day waves increased the newly built beach. A record of these changes is left in the abandoned beaches and the marshy stretches between them which now lie within the present beach line.

Many examples of similar shore features can be found along the Patuxent and the Potomac. The Magothy and the Severn, in the sandy and clayey cliffs along their shores, also furnish favorable opportunities for such features; but the estuaries of the Patapsco, Gunpowder and Bush rivers generally have such low and marshy banks that there is no ready source for the sand necessary for the construction of beach topography.

### *Recent Stream Changes.*

Mention has already been made in the appropriate place of the changes which have taken place in the streams and coast lines of the Eastern Shore during historic times. The same may be found on the Western Shore. When the country about Baltimore was first settled the many small creeks and the larger rivers offered, in their drowned lower courses, convenient harbors and landing places which were more or less accessible from the interior. At that time schooners of good size and moderate draft could lie alongside the wharf at Elkridge Landing loading with the iron obtained from the neighboring deposits in the Potomac group of formations. To-day the river is so choked with the sands, mud and gravels which wash down from the

Patapsco gorge and from neighboring hills, that large vessels can no longer sail so far up the river. Every year the floods and freshets bring down more waste from the land and add it to what has already been deposited, so that the channel grows steadily shallower and the landing grows less and less accessible.

The Anacostia river has had a similar history. Down to the early days of the city of Washington this stream was navigable for several miles from its mouth. To-day the channel and valley are so choked by the silt which the stream brings down that during high tide there is scarcely a foot of water on the broad flats which fill the streamway, and at low tide acres of marsh are laid bare. Thus within a hundred years this stream is seen to have effected great changes in its channel by deep accumulations of detritus derived from the surrounding hills.

One other instance of similar filling-in of a stream channel during historic times may be cited. Somewhere about 1785 Piscataway creek in Prince George's county was a navigable stream as far up as the town of Piscataway, which is now about two miles from tidewater of any depth. "At that date," says Alexander, "it certainly afforded a channel for vessels of good draft up to and a little beyond the Tobacco Warehouse." In 1835, however, the tortuous channel had so far filled up with mud and alluvium that the depth of water "at quarter ebb" was only 1 foot 10½ inches, and at high tide was only three feet. Moreover, at that time the processes of shoaling seem to have been active. J. H. Alexander says: "The progressive changes attributable to these causes [*i. e.* those causing deposition of sediment by checking the flow of the current], if they are to be judged from the effects of the last two years, are going on with considerable rapidity. Shoals of soft mud and shells, which were passed over at that period [1785 circ.], are now islands, covered with marine grasses and aquatic plants, and submerged only at high tide; and the public landing, once at the warehouse and afterwards nearly half a mile below it, is now difficult of access and appears to be fast receding down the river.[1] Since 1835 no record is found of further changes

[1] J. T. Ducatel and Alexander, J. H., Report on the New Map, etc, 1835, pp. 11 and 12.

in this region, but there is no apparent reason for doubting that the filling-in then in progress has continued to the present time.

These instances could be multiplied, but they leave no room for doubt that the strong tendency of all the smaller and most of the larger tidewater streams of Southern Maryland, as well as those of the Eastern Shore, is to fill up their channels with the detritus which they carry.

## ECONOMIC PHYSIOGRAPHY OF THE COASTAL PLAIN.

### *Soils.*

The various geological stages through which the Coastal Plain has passed have had considerable influence upon the soils, and through them upon the crops of the province. The early strata, those of Cretaceous and Eocene age, which are best developed in parallel belts along the northwestern boundary of the Coastal Plain, are sandy loams which yield good returns of fruit and garden truck. In this belt the most prosperous peach- and other fruit-farms have been located, and large quantities of fine peaches are still shipped from the northern counties of the Eastern Shore. The same belt extends northeastwards into Delaware and New Jersey where similar crops are raised. These strata carry with them a natural storehouse of valuable fertilizer in the form of greensand or glauconitic shell marl. In the early days of Eastern Shore farming this marl was much used as a fertilizer, particularly in Cecil, Kent and Queen Anne's counties.

In the central and southern counties the clayey loams which come from the Miocene or Chesapeake deposits afford extensive areas of good wheat, grass and tobacco lands, which formerly were of great importance to the state. Since the rapid development of the wheat fields of the West, however, the yield of these lands has grown comparatively insignificant, so that at present the farmers are not able to make wheat crops pay even by the aid of expensive fertilizers. Among the best-paying crops of the Coastal Plain are the products of the lighter sandy loams of the Pliocene (Lafayette) and Pleistocene deposits. These soils cover the whole Eastern Shore south of the Choptank and are also of importance on the more dissected Western Shore. Large and early crops of berries and melons are annually shipped

Fig. 1.—TOPOGRAPHY OF THE NORTHERN COASTAL PLAIN, IN CECIL COUNTY.

Fig. 2.—FARM-LANDS OF THE COASTAL PLAIN, IN TALBOT COUNTY.

from the cultivated areas of these soils, and the canning of tomatoes, corn and other products constitutes one of the important industries of the province.

### *Waterways.*

The post-Lafayette and the post-Pleistocene submergences of the Coastal Plain have been of immense benefit to the inhabitants of Maryland. As a result of the drowning of the Chesapeake river ocean-going vessels are admitted as far inland as Georgetown, D. C., Baltimore, Havre-de-Grace and Chesapeake City. Valuable harbors also are provided, so that a large share of commerce has been attracted to Maryland shores. Besides interstate and international trade which is thus favored by the configuration of Chesapeake Bay with its deep exit to the high seas, trade within the state is greatly benefited by these waterways. That geologically recent submergence whereby the river valleys carved in post-Pleistocene times were drowned for more than half their length gave to the inhabitants of the Coastal Plain the most favorable facilities for easy and cheap transportation of their crops. The estuaries then formed are the entrances to tidal streams that penetrate into the very heart of the rich lands. They are generally of sufficient depth to admit the light-draught steamers plying on the waters of Chesapeake Bay and the numerous wharves which are encountered on ascending any one of the navigable creeks testify to the readiness with which the people have availed themselves of their natural opportunities. In the proper seasons these wharves may be seen piled high with the crates of fruit and other products which are being sent to Baltimore for distribution among the neighboring states.

Besides thus affording easy paths of intercourse with other important sections of the state the estuaries yield peculiar and characteristic products of their own. The same streams which, during the summer, are the arteries and highways of a commerce based on the products of the soil, become in winter the fields of one of Maryland's greatest industries—the oyster fisheries. Great quantities of these oysters are annually sent to Baltimore, and their gathering has given rise to a race of hardy fishermen and expert sailors only excelled by the codfishers who sail every year to the Great Banks of Newfoundland. The oyster-canning industry, whereby the interior of the continent is supplied with canned oysters, has also arisen as an indirect result of the post-Pleistocene drowning. The diamond-backed terrapin, the duck and the other wild fowl of the littoral marshes also deserve a place among the list of resources which the geographic history of the province has bestowed upon this state.

### *Railroads.*

While the many waterways which intersect the Coastal Plain have given boat traffic the best start among transportation facilities, railroads have been built to a number of points, thus connecting them more directly with the vigor and energy of the great commercial centers of Philadelphia and New York. Generally the railroad, seeking as it does that course which requires the least modifications from the natural topography in order to make an easy grade, has to pursue a more or less tortuous route. On the Eastern Shore the low and almost insignificant character of the divides and the shallow stream valleys permit the roads to run in very direct routes from one objective point to the next. A glance at the map of the state shows these routes and the indifference which they display towards the divides. It is also noteworthy that, although touching at several waterside towns, the railroads are confined on the whole to those wider portions of the small peninsulas where the hauling distance to the boat lines becomes something of a factor in the cost of transportation. By reaching these remoter points they are thus able to maintain a foothold in spite of the lower rates offered by the boat lines. On the peninsula of Southern Maryland the one railroad and its branch are compelled to hold pretty closely to the divide, as a short distance on either side the country becomes so cut up that it would be wholly impracticable to build a line. This is particularly true of the southeastern portion of the peninsula in Calvert and St. Mary's counties.

### *Effect of Topography upon the Inhabitants.*

When the early settlers came to Maryland they found the tracts of the Coastal Plain occupied by peaceful tribes of Indians who lived by fishing in the deeply indented rivers and hunting through the pine and hard wood forests which covered the interstream areas. The settlers themselves took to farming, encouraged by the rich soils, and also obtained plenty of fresh fish and oysters from the neighboring waters. Soon large and prosperous plantations grew up, which afforded by their products good incomes to their owners. The earlier inhabitants were thus mainly agriculturists. As the value of the oyster beds increased and the demands for the oyster grew the race of oystermen sprang up. These men naturally settled along the shores near their work. At present the two classes, which originally must have been somewhat mixed, can be clearly distinguished, the regular farmer keeping to the higher interfluviatile areas, while along the shores and in the vicinity of the large towns are the houses of the oystermen. On the Western Shore the dissection of the interior lands near the Bay has handicapped the farmer very decidedly, while the deep rivers and estuaries give good opportunity for the fishermen to ply their trade.

Thus the geological and physical features of the Coastal Plain, which are the direct results of its geological history, are seen to have almost wholly determined the pursuits and the habits of its settlers and inhabitants.

## The Piedmont Plateau Province.

### BOUNDARIES.

The Piedmont Plateau province is so called from its position along the eastern foot of the Appalachian ranges. It includes the broadly rolling upland of moderate elevation which extends from the eastern slope of the Blue Ridge and Catoctin mountain eastward to a line which runs approximately parallel to the coast, and marks the western limits of tidewater. This line extends from New York past Philadelphia, Baltimore, Washington, Richmond, Raleigh, and Augusta to Macon, Georgia, and along a comparatively narrow zone, is characterized by turbulent channels with waterfalls, cascades and rapids. To the west the streams may have long quiet stretches, while eastward all the streams open out into placid tidal estuaries. This eastern boundary of the Piedmont Plateau is so noticeable a feature that it was early recognized and named the Fall Line from the manner in which it affects the streams. The Fall Line is really a zone several miles in width and probably marks a simple monoclinal flexure or a series of slight faults whose downthrows are towards the east. The western boundary of the province, formed by the eastern base of Catoctin mountain, is a clearly defined topographic feature, the cause of which will be later explained.

As would be expected when topographic boundaries are so well defined, the geologic and structural boundaries are almost equally distinct. On the east along a crenulate line which often coincides with the zone of falls or the Fall Line, lie the extreme western limits of the Coastal Plain sediments. These horizontally bedded and poorly consolidated deposits lie across the bevelled edges of the folded and crumpled crystalline rocks of the Piedmont Plateau, and present such a marked stratigraphic and lithologic contrast to them that the geologic boundary between the two provinces is sharply defined. The lack of completely consolidated layers in the Coastal Plain deposits has prevented the development of marked escarpments which, by their steep inland-facing front-slopes and long, gentle seaward-dipping back-slopes, would more clearly define the limits between the two provinces. On the west the transition from the highly altered crumpled schists of the eastern part of the province to the usually unaltered and less severely folded and faulted strata of the Appalachian region is not as sudden and well marked as the change from the Coastal Plain. From the crumpled gneiss of the eastern portion the Plateau extends across the highly plicated, but less profoundly metamorphosed, phyllites which form most of Parr's Ridge and its western slope. Farther west, along Catoctin mountain, in the uparching and great overthrust faultings of the limestone and quartzite upon the igneous rocks of the Blue Ridge, the structure approaches that of the Appalachians. Although the change in structure is thus gradual, yet the topographic change is more marked. The reason for this is that the great overthrust faults along the flanks of the mountains have elevated the hard quartzite which forms the crest; and subsequent denudation has worn away the softer rocks on either side. A similar explanation applies to Sugar Loaf mountain, south of Frederick.

The Piedmont Plateau, as it has thus been bounded on the east and west, extends from Alabama to New York, and an homologous district can be traced farther northward, where it embraces Rhode Island, Connecticut, Eastern Massachusetts and the coastal portions of Maine and New Hampshire. Maryland, therefore, embraces only the small trapezoidal-shaped portion which is included by the Fall Line and Catoctin mountain, the Potomac and the southern boundary of Pennsylvania.

## TOPOGRAPHIC ELEMENTS OF THE PROVINCE.

Viewed from any of the higher points of the Piedmont, such as the granite knoll just east of Cockeysville or, better, the divide between the Big and the Little Gunpowder Falls northeast of Glencoe, the topography resolves itself into three different classes of features. The first in importance is the broad rolling surface which extends in every direction as far as the eye can reach. Over this general surface are low knobs and ridges which seem to rise a little above the general level of the plateau. Finally, below the general level, numerous streams have sunk channels and valleys which at first escape notice, since all except the nearer valleys are masked by the rolling hills of the plateau upland. The following discussion is divided into three corresponding sections, namely, the Upland, the Valleys in the Upland, and the Residual Masses above the Upland.

### *The Upland.*

As has been remarked, the most striking feature in the topography of the Piedmont Plateau is the very even sky-line given by its many hills, whose rounded tops rise very nearly to the same plane. Could the valleys which have been cut out in the plateau be filled again, it is easy to see what the surface thus restored would look like.

Between the present streams, and at the points farthest from the channels, the divides have low, flat, convex curves, but as the present streams are approached the gentle arches of the divides change to equally gentle concavities, which are sharply interrupted by gorges. The restored surface then would not be a perfectly even one, but would reveal a country of low, well-defined divides whose streams flowed through broad, open valleys bounded by gently sloping hills. This former surface, now a dissected upland, may be easily traced across Cecil, Harford, Baltimore, Howard and Montgomery counties, and through portions of Carroll and Frederick. Extensive areas of the earlier surface that have escaped dissection may sometimes be found where the land is drained only by very small streams at some distance from the larger and more active rivers. Such remnants are especially well preserved in the district along Parr's Ridge, on the two circumscribed patches of granite and gneiss, one of which lies north of Green Spring Valley and the other across the marble belt to the northwest of Towson, and on the upland between Big and Little Gunpowder Falls.

This old surface, which seems to approach very closely to the conception of a peneplain, is shown by the Hypsometric Map of Maryland not to be perfectly horizontal but to rise gently westward. Starting with an average elevation of about four hundred and fifty feet in the vicinity of the Fall Line, a steady rise of about twenty feet to the mile brings it to an average elevation of eight hundred and fifty or nine hundred feet along Parr's Ridge. This ridge forms the divide between the streams flowing eastward across the Piedmont Plateau into the Chesapeake Bay direct, and those which flow first westward to the Monocacy and thence through the Potomac to the Bay. Beyond Parr's Ridge the general surface of the Plateau at first descends somewhat rapidly, and then, after reaching the Triassic (Newark) deposits, very gently to the Monocacy. From the valley of this river the general surface ascends by stages to a bench along Catoctin mountain, on which Mt. St. Mary's College and Thurmont are located, at an elevation of about six hundred feet. The Upland may thus be considered as divided into two portions by Parr's Ridge, and each part will be found to have its own peculiar characters.

It appears, then, that the Piedmont region is much like a gently rolling plateau, whose surface, traversed from southwest to north-

east by the dividing line of Parr's Ridge, slopes gently eastward and somewhat more sharply westward. This plateau surface differs from that of the most widely recognized types of plateaus, since it does not appear to be in any way dependent upon or the result of the structural features of the land-mass which it characterizes. In this respect it stands in strong contrast with the high plateaus of Arizona which owe their level, even surfaces to the horizontal position of the strata. Nor can it belong to the class of almost featureless plains, which appear where seas or lakes have left heavy deposits of sediments, as is the case of our own Coastal Plain. On the contrary, the highly inclined and folded crystalline rocks which compose the eastern portion of the plateau, as well as the more yielding faulted blocks of the Monocacy valley, are indifferently bevelled off, and the folds truncated by the surface of the upland.

The intricate foldings, as well as the great chemical and mineralogical changes which the rocks of the Piedmont Plateau have undergone, indicate that they once formed the deep-seated roots of more lofty mountain ranges. The sediments of the Appalachian Province also point to the same conclusion. In order to reach the surface of the land where they are now exposed to view, these rocks must have been subjected to long-continued and active erosion. The reduction of that lofty range could have been accomplished either slowly by the waves of the ocean, or more rapidly by the steady attacks of the elements. The probabilities are largely in favor of the second explanation.

As one traces the level of the Piedmont upland beyond the bounds of the province itself, several interesting facts are learned, which are important to one who would know the complete history of the Plateau. Within the Piedmont Province this general surface is found to cut across the tilted and now deeply dissected beds of the Newark formation; where these have been removed, the Silurian limestone beneath is seen to be below the general level of the upland. Tracing this surface farther westward the even crests of the Blue Ridge, North mountain, Warrior's Ridge, Dan's mountain, Savage mountain, and many others seem to properly form elements of this almost plane surface. Northward and southward similar elements may be found such as the crests of Kittatinny and Schooley's mountains in New Jersey, and Massanutten mountain in Virginia. In fact, the Piedmont Plateau upland is generally regarded as being but the seaward remnant of a broad, gently rolling surface, which once extended westward beyond Alleghany Front, northward along the Appalachians into New York and New England and southward across the Cumberland Plateau of Tennessee to an unknown distance. This broad plain was cut indifferently across crystallines and folded sedimentary strata and was produced during the final stages of that long-continued denudation which has resulted in exposing the roots of the Piedmont mountain chain. Since the days of its formation, the surface of this old lowland has been elevated and much dissected by erosion, but there is every reason to believe that the high mountain crests are remnants of the once extensive peneplain. This peneplain was first described and studied in Pennsylvania and New Jersey, and was named by Professor William M. Davis of Harvard University the Schooley Peneplain,[1] after the mountain of that name whose crest line is one of the striking remnants of its surface.

The geological periods during which the peneplain was produced may be determined quite definitely by at least two lines of evidence. First its surface is found to bevel strata of all ages from the Archean to the Triassic. This fact fixes its maximum age; it cannot be older than the youngest rocks upon which it has been carved. The peneplain, therefore, must be younger than the Triassic or Newark beds which it traverses in the valley of the Monocacy, in the New Jersey area and in the broad valley of the Connecticut. In the second place, any strata found deposited upon the peneplain must be younger than that surface, and vice versa the peneplain must be older than those deposits. Now it is possible to trace the general surface of the Schooley peneplain to the very edge of the continuous boundary of the oldest Coastal Plain sediments, and, outside this boundary, scattered outliers of those strata are found resting upon the uneven sur-

[1] Davis, W. M., "The Rivers of Northern New Jersey," Nat. Geog. Mag., 1890, vol. ii, pp. 81-110.

face of the plain. The geological map of Maryland shows very clearly how the Maryland portion of the peneplain passes beneath the Coastal Plain strata, and, indeed, everywhere along the boundary between the two provinces this relation may be clearly made out. The diagrammatic sketches forming Figs. 11 and 12 give some idea of the relations which the topographic features of the two provinces bear to each other. The new geologic map of Alabama also shows very clearly how the folded, faulted and planed-off paleozoic rocks of the southern Appalachians gradually pass beneath the nearly horizontal strata of the Gulf Series of the Coastal Plain. When Davis[1] recognized the significance of this burial of the peneplain surface beneath the Coastal Plain sediments it was believed that the Potomac group, the oldest and the lowest strata found there, was of Lower Cretaceous age. As these strata were found to be made up, in their lowest beds, of materials scarcely removed from their parent ledges, the surface of erosion on which they rested, *i. e.* the surface of the Schooley peneplain, was regarded as the topographic product of erosion during early Cretaceous times. The peneplain has been often called the Cretaceous Peneplain for this reason, and consequently the Piedmont upland was understood to have been produced during Cretaceous times. More extended stratigraphic work in the lower horizons of the Coastal Plain, together with careful studies of the vertebrate fauna and the flora of the Potomac Group, have finally led Clark, Marsh and others to refer the lower beds of this series to the Jurassic. A corresponding change must therefore be made concerning the age of the Schooley peneplain and of the Piedmont upland. Since on the one hand it must be younger than the Triassic beds across which it is cut, and on the other is at least as old as the late Jurassic formations which overlie it, the period of denudation during which it was produced would seem to embrace late Triassic and early Jurassic times.

### *Valleys in the Upland.*

The valleys which have been incised in the plateau are characteristic of the province, but they are not all of the same type. One

[1] Davis, W. M., "The Geological Dates of Origin of certain Topographic Features, etc.," Geol. Soc. Am. Bull., ii, 1891, pp. 545-548.

set of valleys is distinguished by their steep sides and narrow channels, another class has broader valleys with milder bounding slopes and is not as extensive as the first class. Yet a third class has but one representative, namely, the Monocacy with its tributaries, which is distinguished by broad benches at several levels, wandering stream-courses with steep but low side slopes, and channels in which long stretches of smooth water alternate with zones of low rapids and rougher water.

All three classes of valleys are of considerable importance to the inhabitants of the province. By sinking their channels below the general surface of the plateau the streams have cut up or dissected that surface to such an extent that it has become rough and hilly, making the travelling *across* country quite arduous. This discomfort, however, the streams have themselves partly remedied by making their gorge-like valleys just the least bit wider than was needed for their own use, so that the early settlers found room for wagon-roads by the sides of the channels, and later comers have taken advantage of the same features in building their steel road-ways. Furthermore, the steep channels, full of little falls and cascades, which are confined by narrow gorges, offer many sites favorable for the building of mills and dams. A brief consideration of the characteristics and origin of these different types of streams and valleys will therefore be of interest.

The lower portion of the valley of Deer creek in Harford county has almost exactly the characters which distinguished the stream valleys of the old upland before it was dissected. The rounded hills slope gently towards the stream, and pass beneath a rather broad valley floor and flood-plain which accompany the stream for the greater part of its length. The channel itself has, along its lower portion, come slightly under the influence of recent uplifts, so that it is sometimes in a very shallow trench, but most of the time it wanders through the flood-plain unrestrained by walls. The general impression gained from a view of the valley is that of a gently rolling country with broad valleys and gently flowing streams, just such a landscape as is presented to the eye of one, who, standing on one of the upland remnants, by the aid of the imagination restores the old surface of the country. In Cecil county two-thirds of the course of each stream generally flows in such a valley, while the lower third occupies a more rugged channel.

Those streams which empty into Chesapeake Bay, however, south of the Little Gunpowder do not present such characters except in the immediate vicinity of their headwaters. Such streams as the Little Gunpowder, the Big Gunpowder, the Patapsco and the Patuxent, for the greater portions of their courses flow through narrow gorges of gradually increasing depth and width. Although the map shows that the courses of the streams are often somewhat winding, the topographic map, or better still an examination of the streams themselves, reveals the fact that this indirectness in course is not the result of wanderings over modern flood-plains, but that the gorges themselves follow more or less closely the swings and turns of the channel. Along the largest streams, such as the Big Gunpowder and the Patapsco, there is barely room to admit the railroad tracks and an occasional wagon-road. Among the streams belonging to this class the channel course is not affected to an important degree by the different rocks through which it cuts and in this respect differs from certain other streams to be noticed below.

These streams are also characterized by channels whose varying grades reveal how recent an event, relatively speaking, was the elevation which caused the streams to thus entrench themselves below the plateau. Beginning at the mouth of any one of these streams, as the channel is followed up-stream, its grade is found to be very steep for several miles. The distance to which this steep grade extends depends upon the size of the stream and to some extent upon the character of the rocks flooring the channel. Plate XIX shows that the Big Gunpowder has this steepened grade as far as Loch Raven, or for a distance of something over eighteen miles up-stream from its mouth. Above this point the Gunpowder runs in a limestone valley for eight miles until reaching Warren Mills, beyond which the channel is continuously on gneiss, phyllite or serpentine to its source in Pennsylvania. The easily reducible marble above Loch

Raven has not maintained the steeper abnormal, convex grade maintained below that point, and when the gneiss is again reached the grade has changed to the normal concave character.

Gwynn's Falls and Jones' Falls (Plate XIX), streams of about equal size, have both pushed their steep grades about eight miles up-stream, reaching Powhatan and the Lake Roland dam respectively. These are smaller streams than the Gunpowder, and therefore have not had the volume and the power needed to reduce their grades to as low a slope, or to push the steep grades back as far as the latter stream has done. The zone of falls, approximately eight miles wide, which is here described, marks the position of the zone of displacement, which has been denominated the "Fall Line." All these streams with their gorges and troubled rock-ribbed channels show that they have not yet succeeded in reducing their courses to even and matured grades. These immature characters do not generally extend, however, quite up to the heads of the streams. For several miles from their sources streams like the Gunpowder, Gwynn's Falls and the Patapsco have the broader, open valleys and quiet currents which characterize mature drainage and, like the lower course of Deer Creek, reproduce the old upland surface.

Certain tributaries of the streams above referred to occupy valleys which depart from the normal type of side-valleys of youthful streams. Instead of being confined between the steep walls of narrow, ravine-like gorges, as is usual for the tributaries of large streams in areas recently elevated, these favored brooks flow through relatively broad valleys with fertile floors, but steep sides. Western Run and a small tributary of Beaver Dam creek, Dulaney's creek and Mine Bank run are a few of the streams belonging to this class. Jones' Falls is an independent stream which also belongs in this class. Most of these broad valleys have been opened out on areas of soluble marble, leaving the surrounding gneiss and granite areas standing prominently above the lowlands. In the case of the headwaters of Little Deer creek, however, a broad lowland bordering the stream has been opened out on the band of yielding and crumbling phyllites, which runs northeast and southwest across Harford and Baltimore counties. The same is true where some of the tributaries of Western Run cross the phyllite, although in the latter case the stream is flowing not parallel with but across the strike of the foliation. Besides their breadth and their arrangement parallel to the general direction of the structure of the country, these broader valleys are in some cases also distinguished by containing remnants of the earliest strata of the Coastal Plain series. These remnants are of two horizons. One consists of the variegated clays and washed gravels, which form a portion of the Potomac Formation, and it is found chiefly as small patches in the Green Spring Valley, in the vicinity of Lutherville and about Oregon. The other horizon is that of the Pleistocene, whose deposits consist of gravels and sand brought in by the larger streams. These deposits are much more extensive than are those of the Potomac, remnants being widespread over the valleys about Cockeysville, Dulaney's Valley, Green Spring, Mine Bank run, and the valley of Western Run. The Pleistocene may also be traced along the narrow gorges of several of the streams which, for portions of their courses, flow through the open valleys.

The presence of remnants of the Potomac and Pleistocene formations in these valleys gives some clue to the geological period during which they were etched out. Since they were sunk below the general level of the upland they must have been one of the sets of valleys carved out by streams acting under the revivifying influences of an elevation just succeeding the period in which the upland was formed. In the preceding section it has been shown that the upland surface, whether a peneplain or a surface of advanced maturity, was produced in the interval between the elevation of the Newark and the early portion of Potomac time. These valleys are, therefore, younger than earliest Potomac time. At the same time, since they contain Potomac deposits, they cannot be younger than late Potomac time. As these deposits are of later Potomac (Patapsco) age the valleys containing them must be of middle Potomac date. Recent studies in the Potomac group have led to its being referred in part to the Jurassic and in part to the Cretaceous, and from the data given above the date of formation of these valleys is probably very late Jurassic or early Cretaceous.

In the western half of the Piedmont Plateau, within the drainage of the Monocacy river, small level-floored valleys, eaten out along limestone lenses, are also frequently met with. The limestone of these valleys is regarded by many as identical with the Cambro-Silurian limestone of the Great Valley and of Frederick, but a study of the stratigraphic relations in the Monocacy valley makes it appear very probable that these lenses were completely buried by the estuarine deposits of the Newark (Triassic) formation. No remnants of this formation were found within these limestone valleys so that it cannot be definitely asserted that they are of pre-Newark age. On the other hand the fact that they are invariably occupied by small streams, which have there developed subsequent courses, rather indicates that these valleys have been developed during more recent times than have their counterparts in the east.

West of Parr's Ridge the upland declines rather gradually while on the phyllites and disappears entirely when the eastern boundary of the Newark formation is passed. On these yielding rocks a terraced and dissected lowland has been carved out. Its highest level is an extensive but dissected plain maintaining an almost uniform height of five hundred feet above tide from the Potomac along Catoctin mountain to Emmitsburg. This elevation increases slightly northward in Pennsylvania, but is remarkably constant through Maryland and Virginia. Although it was formerly a continuous lowland extending across the valley of the Monocacy, subsequent elevations have caused large portions of the surface to be removed by erosion. The extent of the remnants is variable; large areas may still be seen about Frederick and to the south, but northward towards Emmitsburg the surface is represented by areas only a mile or two in width.

Below this higher level the Monocacy has at different periods in the past cut lower and less extensive valley floors or valley lowlands, which now appear as broad benches of varying width, overlooking the present stream channel. At a level of four hundred and fifty feet or fifty feet below the uppermost surface is the first of these subsequent terraces. This is the most persistent and uniform of the lower terraces and often attains a width of three to five miles. It is best seen over the district between Thurmont and Emmitsburg.

Following the present channel of the Monocacy, and sometimes traceable for short distances up the larger side-streams, is a third terrace, the lowest of the old valley floors. It has an elevation of about three hundred and fifty feet in the vicinity of Frederick and southward, rising very gradually northward where it is more widely dissected and removed. The width is variable, but rarely exceeds a mile. A steep slope leads down from the second terrace. Below this lowest bench the present channels have entrenched themselves to a depth of one hundred feet or less.

The channel of the Monocacy, though of gentle slope and graded for considerable stretches, is often interrupted by low unreduced ledges. It generally lies five or six feet below an extensive flood-plain which is submerged for more or less protracted periods, several times a year. Side-streams joining the Monocacy have trenched the flood-plain during its unflooded periods, and have along their lower courses developed smaller flood-plains of their own. The channels of these tributaries are not as perfectly graded as is that of the main stream, and frequent low falls interrupt them.

The lowlands eroded on the yielding rocks of the Newark formation are one of the striking features of the Piedmont Plateau throughout its extent from Massachusetts to Virginia. The lowland of the valley of the Connecticut river is the most extensive and best known of these valleys. As the Plateau has there suffered greater elevation the valley is cut to a greater depth below it than in the case of the Monocacy, and is therefore a more pronounced depression in the general topography of the upland. The valley of the Connecticut, however, was within the limits of the area covered by the great Ice Sheet of the last Glacial Epoch, and as a result of modifications imposed upon it by the ice and the glacial rivers its minor topography is different from that of the corresponding valley in Maryland which did not come under these influences.

There are then, as has been shown, three types of valleys sunk below the Piedmont upland: the narrow circuitous gorges with steep sides and rapid currents and closely fitted by the streams which made them; the broader, level-floored valleys developed along yielding limestone or phyllite and occupied by slightly meandering streams which may later on enter narrow gorges, and the broad even-topped, terraced lowland of the Monocacy and its tributaries.

*Residual Masses above the Upland.*

As the general surface of the Piedmont Plateau is traced northward into New England it is found that there are several prominent elevations which rise sharply above the general level of the plateau. Mount Monadnock, Mount Ascutney, and Mount Wachusett are prominent examples of these features. Going southward into the Carolinas similar prominences may be observed, but more striking than these is the manner in which the surface may be traced in and out among the high peaks of the Black mountains, particularly in the vicinity of Asheville. These various mountains and peaks are evidently portions of the old land area which for some reason was not reduced during the period of base-leveling that produced the even surface of the upland. They may owe their present prominence to one of two causes, either they are composed of rocks of superior resistance to those surrounding them or they were situated so far from the seacoast that sufficient time did not offer in which the streams could work back to and reduce them. Mount Monadnock was first described as being such a remnant, and its name has been adopted as a designation for all more or less isolated residual masses left standing above the general level of the peneplain.

Maryland presents only a few low examples of such *monadnocks* above the general upland of the Piedmont. Rocky Ridge and its fellow, Slate Ridge, both in Harford county, are the best-marked illustrations of this class of topographic forms. Both ridges have but a slight elevation, not more than one hundred feet above the plateau surface, and owe their prominence to the fact that they are composed of unusually resistant rocks. Rocky Ridge marks a band of quartzite and conglomerate, and Slate Ridge, as its name implies, is the outcrop of a band of roofing slates which is pinched into the phyllite. Plate I shows something of the character of the crest of Rocky Ridge, and a general view of the west side of Rocky Ridge is given in Plate XVII. The same quartzite which forms Rocky Ridge occurs along the south side of Green Spring Valley and forms Setters Ridge at the west end of that depression, but this ridge is less marked in elevation and not easily distinguished from the other inequalities of the general surface. In the valley of the Monocacy, and rising above its floor to an elevation of twelve hundred feet, stands Sugar Loaf mountain, clearly a monadnock with respect to the broad, even five hundred foot level of the valley. The mountain is also a monadnock with respect to the Piedmont upland which, crossing Parr's Ridge at eight hundred and fifty or nine hundred feet, was found to decline to six hundred feet along the base of Catoctin mountain at Mount St. Mary's College, Emmitsburg.

### *Summary.*

The general topographic features of the Maryland Piedmont Plateau have been found to be similar to those of the same topographic province along other portions of the Atlantic Slope. The most important topographic feature is the rolling surface which forms the upland of the Plateau. This surface was brought to its former slight relief by the action of rivers and streams, and was bevelled down across hard and soft rock indifferently. It has a general gentle rise westward from an elevation of four hundred feet at the Fall Line to a maximum of nine hundred feet at Parr's Ridge, whence farther west it declines to an average elevation of six hundred feet along the base of Catoctin mountain. Above this general level rise low residual masses or unreduced monadnocks, such as Sugar Loaf Mountain and Slate Ridge, while below the upland narrow gorges have been cut out, limestone lowlands have been etched, and on the Newark formation broad, terraced valleys have been carved.

## THE ROCKS AND THE STRUCTURE OF THE PIEDMONT.

In order to understand the systematic development of the Piedmont drainage, the various rocks, their relative resistances and their arrangement with reference to each other must be considered.

### *The Rock Types.*

The rocks of the Piedmont province may be conveniently considered in two divisions, an eastern and a western one, as was the topography.

The eastern portion of the Piedmont, eastward from a line joining Seneca on the Potomac and Manchester, Carroll county, is largely composed of rocks which are now completely crystalline and show little evidence of ever having been deposited as sediments. Only a few scattered areas of the eastern division are composed of semi-crystalline rocks which have been altered from former sediments to their present state by the action of great, long-continued heat and pressure.

The crystalline rocks are probably older than the semi-crystalline metamorphosed rocks, possibly representing the lower members of the Paleozoic series to the west, and are generally referred to the Archaean or the oldest of the geological eras. They include granites, diorites, peridotites, pyroxenites, gabbros, marbles, quartz schists, and gneisses. For the present purposes these rocks need not be specially discussed. The granites and the closely related diorites differ slightly in color and in the characters of their dark-colored constituents. They are both quarried extensively. Both yield to erosion at about the same rate. The darker, heavier rocks, called gabbro, cover an area about equal to that of the granites and diorites but are concentrated about Baltimore, Havre-de-Grace and Rising Sun and in a belt through central Harford county. On weathering the gabbro usually yields a characteristic heavy reddish soil due to the large percentage of original ferro-magnesian constituents. On the accompanying map (Plate XVI), the gabbro, granite and diorite have all been given the same symbol with the gneiss which covers the larger portion of the eastern Piedmont slope. The latter is a normal gneiss of a white, a dark gray, or blue color, which has been very completely metamorphosed by repeated squeezings. It has a complicated structure, shown by its large and fine crumplings and plications, and is composed of bands of varying width which often show marked differences in resistance to erosion.

The marbles are completely crystallized saccharoidal masses which often show dolomitic bands with impurities in the shape of irregular zones of accessory minerals, such as brown mica, white hornblende, tourmaline, etc., resulting from a recrystallization of the original

FIG. 1.—PIEDMONT PLATEAU, LOOKING WEST FROM SLATE RIDGE.

FIG. 2.—HERRING RUN, BALTIMORE COUNTY.

impurities. Bands of quartz schist, composed chiefly of secondary quartz and divided into numerous planes by layers of flaky mica often accompany the marbles from which they are sharply defined, while they change gradually into the gneisses which may be present on the other side. The quartz schist is closely allied mineralogically to the metamorphosed sandstone and conglomerate now appearing as the Cambrian quartzite of Rocky Ridge in Harford county. Next in importance to the quartzites and schists are the peridotites and pyroxenites. These are dark, medium fine-grained rocks of considerable specific gravity which occur, not over large areas, but in restricted patches. One long, narrow, irregular band is located in northern Harford county running northeast and southwest, another is about fifteen miles long and runs northeast-southwest midway between Sykesville and Woodstock. Just north of this band is a large circular area at Soldier's Delight and an irregular one lies between the latter point and Catonsville. Both varieties of these basic rocks are subject to a constructive alteration or chemical change which produces serpentine or steatite according as the original rock was peridotite or pyroxenite. The Bare Hills is composed of a small patch of the altered rock serpentine.

A narrow interrupted diabase dike extends from a point west of Guilford, northward and eastward through Worthington Valley past Parkton, and so through the northwest course of Harford county out of the state. This rock weathers very easily into a red soil, leaving irregular fragments scattered over the surface or in the loam. Since in this portion of the state it does not show any characteristic topographic form it has been colored like the gabbros with which it is closely related.

The evidently clastic rocks of the eastern Piedmont are the quartzite already mentioned in connection with the quartz schist and detached areas of the same phyllites which chiefly underlie the western division. Beginning in a small point north of Reisterstown, the phyllites extend northward, then turn northeastward, gradually widening near Parkton and pass out into Pennsylvania. These rocks are finely laminated sericite and chlorite schists, which are much contorted and finely puckered in the eastern division. They yield very readily to erosion. In their midst about Cardiff they have pinched in a deep lens of fine-grained blue-black roofing slate, on either side of which is a band of the quartzite conglomerate. The slates, the quartzite and the conglomerate, and the phyllite are distinguished by separate symbols on the map.

On the west the rocks of the Piedmont Province are semi-crystalline, crystalline and clastic in nature. The semi-crystalline rocks are the phyllites and their associated crystalline fine-grained limestones. The phyllites, which are much faulted and puckered, often hard to separate from the gneiss of the eastern division along the eastern slope of Parr's Ridge, become less and less disturbed westward. The crystalline limestones, or fine-grained marbles, occur particularly in the vicinity of Westminster and Union Bridge. The eruptive rocks of a basic character found in the phyllites have been so highly altered by pressure that they now appear as chloritic and epidotic schists. These once wholly crystalline rocks are probably of Archaean age; but other basic eruptives in the form of diabase dikes and sheets were pushed up through the Newark strata during Mesozoic time. These dikes are but little altered, but the baking to which they subjected the adjacent sandstones and shales has hardened the latter and changed the prevalent red color to a bluish-black or a deep brown.

Among the remaining sedimentary rocks in the western portion of the Piedmont are the soft red shales and sandstones of the Newark, the Shenandoah limestones of the Frederick valley and the Cambrian quartzites.

### *Topographic Valences of the Rocks.*

The various rocks enumerated above, by reason of the different degrees of resistance which they offer to weathering and erosion, control in great measure the topographic features of the province. Although the facts at hand are insufficient for a detailed discussion of the topographic characteristics of each rock type, they may be discussed under the following heads:

The *gneiss*, *granites* and *gabbro* all offer about the same resistance.

They form by far the greater portion of the general surface of the plateau, and are characterized by rounded hills and gentle slopes on the old upland surface. The steep walls of the recent gorges and the slopes of the hills leading down to the broad valleys are also characteristic of these rocks. With them have been grouped the diorite and the diabase because of their small areal extent and essentially similar topography. There are bands of varying resistance distributed throughout the rocks of this group, particularly the gneiss, which is by nature of variable lithologic character. These zones are, however, so irregular in size and position that for the present one cannot say more than that they follow the general direction of the gneiss foliation. They are expressed in the topography by occasional expansions or contractions in the gorge-floors and by softening or intensification of the steep contours of the valley walls.

Next in areal importance come the *phyllites* of the western and the northern central portion of the Piedmont. In the tongue-shaped area of the latter section the phyllites produce more rounded hills and gentler slopes than are general on the gneiss. Where streams cross the band, as Black Rock run does, for example, the valleys are much broader and have milder channel slopes than those which characterize the same streams in the gneiss. Deer Creek has developed a fair-sized subsequent tributary on the phyllites, and other streams crossing it sometimes send out little feeders along the strike of the formation. The large area of phyllites forming Parr's Ridge and part of the western slope present very similar topography but on a more extensive scale. The small headstreams of the Monocacy drainage carve deep narrow valleys, but they have more rounded slopes and wider floodplains near their headwaters than do corresponding small streams on the eastern slope. The prominence of Parr's Ridge itself is due to its location at the headwaters of the two opposing drainage systems and not to any marked resistance of the phyllitic rocks forming it.

Folded in with the phyllites of the western division are lenses of *limestone* and *marble*, whose high degree of solubility has permitted the hollowing out of broad flat-bottomed valleys. These valleys find their counterparts on the eastern slope of the plateau in long narrow valleys which have been opened out on curving bands of marble. Green Spring valley, Worthington's valley and the related meadow-lands along Western run are typical illustrations. Long Green valley on the Baltimore and Lehigh Railroad is more nearly like the level-bottomed, lens-shaped valleys of the western portion. About Lutherville several smaller areas of marble coalesce and form a broad, open lowland, now slightly dissected. Not all the marble bands of the eastern division, however, have been etched so completely. The two parallel bands of marble lying southwest of Ellicott City are crossed by headwater streams of the Little Patuxent, which are now just beginning to work out valleys little lower than the general upland level. These limestone and marble bands are the weakest topographic factors in the Piedmont complex.

Next to the limestones and marbles in weakness come the various members of the *Newark formation.* These shales, sandstones and limestones form the benches and terraces along the Monocacy river and are wearing away only less rapidly than the limestones and marbles. Where surfaces of erosion are preserved in this formation, as on the benches and terraces, the topography is almost featureless. The slopes from one level to a lower one are usually seamed by small ravines of slight depth and moderate inclination. When streams have cut down to the present level of the Monocacy they have comparatively broad bottomlands along their lower courses and have already advanced beyond Infancy even for some distance up-stream. All these characters obtain in spite of the comparatively recent periods of uplift which the Triassic district has undergone. The diabase dikes which cut the other rocks of the Piedmont and are in the western portion at least of Triassic age, weather so readily that they are of no topographic value when they occur in the gneiss and limestones of the eastern portion. Where they have baked the Triassic shales and sandstones west of Parr's Ridge, however, their presence is revealed by low swells upon the otherwise gently undulating plain. When a stream crosses the diabase dikes the valley slopes of the stream are steepened and numerous fragments occur in the slightly roughened channel.

The most resistant rocks, those forming the most prominent topographic features, are the serpentines, the slates, the quartz schists and the quartzites. The most extensive of these rocks are the serpentines and steatites which, as has been mentioned, are alteration products from peridotites and pyroxenites. As these rocks are the results of changes near the surface they offer much fewer opportunities for chemical and physico-chemical processes of disintegration than do rocks of a different nature. They therefore now stand out as low ridges or rounded knolls above the surrounding gneiss. The serpentine is most striking topographically where it is crossed by streams, for then its resistance to weathering and to the wear of running water cause it to form steep, boulder-strewn, rocky gorges with steep, rough channels. The best illustrations of these characters are found where the North Branch of the Patapsco crosses a broad band of serpentine several miles north of Marriottsville; where Winter's run crosses the same band, and farther north, in Harford county, where a tributary to Deer creek crosses a band of similar rocks. The rounded but barren slopes of the Bare Hills, and the elevated, irregular interstream area of Soldiers' Delight, rising to one hundred feet or more above the surrounding surface, are each caused by the presence of large masses of this rock.

The serpentines are only slightly less prominent than the *slates*, the *quartzites* and the *schists*. These three types form the most prominent eminences above the upland. The quartz schist, or Setters Ridge quartzite, as it is sometimes called, forms a distinct ridge overlooking the marble-floored Green Spring and Mine Bank run valleys. In Harford county the prominent elevation of Rocky Ridge is maintained by a heavy band of quartzite and metamorphosed quartz conglomerate whose unyielding qualities are also responsible for the rock towers and turbulent channel where Deer creek crosses the ridge at "The Rocks." A near view of the water gap and the ridge is shown in Plate I. Slate Ridge is a somewhat broader and less marked ridge situated north of "The Rocks," and is caused by the presence of the band of slates between Cambria, Md., and Peachbottom, Pa. Although the slates of Slate Ridge are probably stratigraphically related to the quartzites of Rocky Ridge, they have been separately colored on the map because of their lithological difference, while for a like reason the Setters Ridge quartzite which is probably a product of fumarole action[1] has been classed with the Rocky Ridge quartzites because of their lithologic similarity.

In conclusion, it may be said that the Piedmont Plateau rocks present different types whose topographic expressions are sufficiently dissimilar to permit of the divisions which have been discussed. These divisions have been represented on the map forming Plate XVI, and the symbols have been arranged, not in a chronological, but in a topographical order. Those rocks which are the most resistant and form the most prominent features stand first at the head of the column. They are succeeded by weaker and weaker rocks until the soluble limestones and the incoherent Coastal Plain deposits are reached.

### *Structure of the Piedmont.*

Whatever may have been the original structure and the stratigraphical relations between the various semi-crystalline and crystalline rocks of the Piedmont Plateau, all traces of these features have been destroyed by the profound dynamical metamorphism to which they have been subjected since their formation. This metamorphism has induced in the rocks a secondary foliation by arranging the mineral constituents in long parallel lines and planes, but this foliation bears no close relation to the possible original bedding planes of the rocks. A cross-section of the plateau shows that the foliation planes dip steeply east and west down towards an axial line which crossing the Potomac near Great Falls proceeds northward past Gaithersburg and Westminster into Pennsylvania.[2] On the western side of the axis of this fan-like structure the strike of the foliation of the phyllites with their infolded lenses of marble is parallel to the axis. On the east the gneiss, with its infolded phyllites and marbles, keep a northeastward course to the latitude of Westminster, then make a sudden turn to the eastward and, following this new direction

[1] See Md. Geol. Survey, vol. i, 1897, p. 163.

[2] Thus it appears that the structural axis is not related to the boundary between crystalline gneiss and semi-crystalline phyllites.

for some miles, the bands of marble, quartz schist and gneiss again turn northeastward. The arrangement of the marble in long parallel bands which make a sudden eastward curve with most of the Paleozoic strata of Pennsylvania is suggestive of an original Appalachian structure. No reliance, however, may be put upon these appearances as indicating the original relations to the gneiss.

The western half of the fan shows a decreasing amount of deformation, although the blue and white Paleozoic limestone about Frederick shows a very considerable crumpling of its bedding planes. Upon the eroded surface of the phyllites and the blue limestone rest the beds of the Triassic sandstones and their intercalated diabase dikes and sheets. The latter are deeply and thoroughly broken up into angular blocks by a great number of fault planes produced prior to the formation of the upland. Many of the fault blocks have been greatly changed from their originally horizontal attitudes, while some may still retain their early positions.

### RELATIONS OF STREAMS TO STRUCTURE.

The structure of the Piedmont Plateau is so different from that of most portions of the earth's surface that the problems connected with the relations between it and the drainage lines found thereon are much simplified. Although the true structure of the Piedmont is probably very much more complex than that of the Appalachian province, the land surface has undergone so many partial or complete repetitions of the topographic cycle that all the influences which original foldings and faultings may have exerted are now unimportant. For this reason it is impracticable, in the study of the Piedmont drainage, to apply the more detailed refinements which Davis, Hayes, Campbell[1] and others have used so successfully in studying the Appalachian streams.

#### *Present Discordant Locations of Streams.*

Any map giving the drainage of the state will show that the streams flowing down the eastern slope of Parr's Ridge to the

[1] Davis, W. M., "The Rivers and Valleys of Pennsylvania," Nat'l Geog. Mag. i, 1889, p. 183. Hayes and Campbell, "Geomorphology of the Southern Appalachians," Nat'l Geog. Mag. vi, 1894, p. 63.

Chesapeake follow approximately parallel courses which have a general southeastward trend.

The general trend of the stream courses is almost exactly at right angles to the slightly eastward curving, southwest-northeast strike of the foliated crystalline rocks which make up the complex series of the Piedmont. As pointed out above, these crystallines embrace numerous bands of resistant rocks alternating with zones of more yielding character. Although resembling the Appalachian mountain district in this respect, even the main stream courses of the Piedmont do not pass from one yielding band to the next as they do in the Appalachians, see Fig. 9, but appear quite indifferent to such variations. For example, the Big Gunpowder pursues a course wholly independent of the numerous broad marble bands which it crosses, while its tributaries—West Branch, Western Run and Piney Run—also traverse indifferently gneiss, phyllite or limestone. The headwaters of the Patuxent south of Marriottsville, the streams of Worthington's valley and Gwynn's Falls near Pikesville are further instances of the lack of co-ordination between the Piedmont rocks and the streams flowing across them. Evidently the streams of the eastern portion of the Piedmont have not long been located in the rocks now exposed or else the law of divides on hard rocks, valleys on soft or yielding ones here finds many exceptions to the rule.

Among the streams of the western section of the Piedmont occur many similar cases of unadjusted or discordant streams. The small portion of the western section shown on the map, Plate XVI, reveals several such cases even among the smaller streams where adjustments are usually most marked. The larger geological map of the state shows a number of westward flowing streams whose courses appear to be quite unaffected by the presence of limestone lenses. The Monocacy itself pursues a course which is at present rather independent of the rocks it crosses. From Emmitsburg southward for thirty miles the main stream and its tributaries flow back and forth across soft shales or sandstones and several times cross the harder diabase dikes. When opposite Lewistown the stream leaves the Newark formation and for twenty miles follows the great band of Shenandoah limestone forming Frederick valley. Not content with this selection the Monocacy again changes, this time from limestone to phyllite, and after meandering back and forth across limestone and phyllite, finally cuts across a corner of the Seneca creek Triassic sandstone to join the Potomac. So imperfectly adjusted a course as this could hardly have been developed upon the rocks of the Monocacy valley as now exposed. The long lenticular area of limestone would surely have exerted control enough to confine the growing stream within in its boundaries.

To sum up it is clear that, as a whole, the streams of the Piedmont Plateau follow courses which have not been strongly influenced by the arrangement of the rocks now exposed to view. Many cases of marked discordance can be found not only among the larger, more powerful streams, but also among the smaller, younger streams where adjustments are most common.

*Normal Arrangement is Accordant.*

If one attempts to construct in imagination the general drainage plan of the Piedmont, as it would appear after having developed through a normal topographic cycle, the present unadjusted drainage stands out quite sharply through contrast. Following on Plate III the general trend of the structure, and supposing that both the Susquehanna and the Potomac through their size were able to maintain their present courses, the general features of the smaller drainage lines may be outlined as follows. The side streams starting from the Potomac and the Susquehanna would be working along the strike of the gneiss, phyllite, limestone, etc., and thus be able to cut out their valleys easily and rapidly. The north and south drainage would thus have distinct advantages over the streams flowing eastward to the ocean, as the latter streams would have to cross the resistant as well as the yielding strata. While one of these eastward flowing streams was attempting to reduce the harder bands a stream working its headwaters from the north or from the south along one of the yielding bands would easily be able to intercept the less favored stream and carry its headwaters off along a course parallel with the strike. The least resistant bands, such as the phyllite extending southwest from the Susquehanna or the limestones running northward from near Point of Rocks, would determine the location of the principal valleys; areas of marble, such as those forming the Texas, Dulaney and the Green Spring valleys, would be obtained by one stream system, while resistant bands, such as the serpentine strip east of Sykesville, would form marked ridges and divides. Such unadjusted courses as that of the lower Big Gunpowder which flows indifferently through granite-bound gorges or broad, marble valleys, or that of Gwynn's Falls which, flowing out of the gneiss, crosses the end of the long tongue of the Green Spring valley marble and turns back into the gneiss again without developing even a fair-sized subsequent along the marble, would not develop under the conditions of a normal cycle.

In general, normally adjusted and accordant drainage lines from the Potomac to the Susquehanna would have located the main divide of the Piedmont along a line running northwest from Baltimore. Secondary divides running northeast and southwest at either end of the main divides would be demanded by the streams flowing into the Monocacy and the ocean. This arrangement with its numerous trellised streams, Fig. 9, would be very different from the present plan in which the main divide runs northeast and southwest and the principal drainage lines are southeastward, while the stream patterns, instead of showing the results of adjustments, pursue random courses which branch in tree-like patterns across hard and soft rocks alike. The question naturally arises, Why do the streams show so little regard for the structure of the province?

*Causes of Present Discordances.*

It appears impossible to explain this discordant drainage by appealing to any of those ordinary phenomena which accompany uninterrupted stream development. The streams under discussion are entrenched to a depth of from one to three hundred feet below the general upland surface of the plateau. If they originated upon this upland, and are now sunk below it simply as the result of uplift, then they should now exhibit the trenched but well adjusted courses of streams which have attained to Maturity, for that was the stage in the topographic cycle reached by the upland before it was given its present elevation. Since it is inconceivable that they could have developed such courses upon the Piedmont rocks under normal conditions, it is necessary to conclude that the present drainage lines were developed upon some other surface under other conditions and that the pattern thus independently produced has been impressed upon the Piedmont in spite of its lack of accord with the structure of the latter area.

The development of drainage along lines independent of the structure of the deeper rocks beneath it is not an unknown phenomenon, although it is not often reported. Those portions of the earth's surface which were the seat of widespread glaciation during the Glacial Period, namely, northern North America and Europe, had their pre-glacial topography more or less completely marked by the deposits which the retreating ice sheets left. Upon this new, constructional, glacial topography new streams of a peculiar kind have originated, and pre-existent rivers have either been blotted out or been materially modified in courses and directions. As the new or modified streams cut down through the glacial drift they have encountered the underlying rocks and have established their courses upon them. These courses, however, having been assumed on the glacial cover are independent of the subjacent structures and their newness is evidenced by the unreduced ledges which cause the many falls and rapids of the streams within the glaciated districts.

The famous cataracts of the Nile are due to the fact that the river, cutting down along a course taken on the surface of Cenozoic deposits, has reached a completely buried, irregular surface of granitic rocks. The Nile first took its course along the slopes of the uppermost rocks. Later, when revived by a geologically recent uplift, it deepened its channel until the granitic ledges became barriers to further downward cutting at those points. A very similar case is that of the rapids in the Grand Canyon of the Colorado. The Paleozoic and younger strata forming most of the canyon walls buried beneath them the Archaean gneisses and granites which the Colorado has now uncovered after cutting down through the softer mantle.

In all of these cases the streams are more or less closely following the courses which they established upon a cover of overlying rocks. After sufficient time has elapsed the covering strata were removed and the streams remain following discordant courses across the older and once buried rocks. There is good evidence in the outliers remaining to show that the eastern portion of the Piedmont Plateau was formerly partly buried beneath a mass of sediments belonging to the Coastal Plain. Similarly, in the western division, the stratigraphic conditions of the main body of the Newark formation and the scattered positions of remnants and gravels of the same indicate that these deposits once stretched over considerable areas of the limestones and phyllites now exposed to view. The thicknesses of both series of rocks were sufficient to quite mask the buried topography and give surfaces entirely independent of the former ones. It is apparent, then, that the conditions necessary for the development of drainage along lines independent of the structure of the Piedmont Province have existed in Maryland. These conditions obtained immediately antecedent to the present, and there is every reason to suppose that they were the controlling factors in the development of the present discordant drainage. On the east the irregular branching of the eastward flowing streams closely resembles the general pattern of the streams of the Coastal Plain province, compare Plates V and VIII, while the general southeastward direction of their channels is in accordance with the general dip of the Coastal Plain surface and strata. On the west the same wandering courses characterize the Monocacy and its tributaries, where they cross the metamorphosed or semi-metamorphosed rocks, as are to be found upon the yielding masses of the Newark beds. Moreover, if the Triassic rocks be restored over the areas whence they have been removed it appears that the Monocacy occupies a longitudinal position just where it would naturally develop if the elevation of the land was not sufficient to reveal the underlying rocks.

More detailed evidence of the origin of the Piedmont streams will be found in a special study of that problem given below. This shows that the streams, after developing courses which were characteristic

FIG. 1.—PATAPSCO VALLEY AT THE MOUTH OF BRICE'S RUN, BALTIMORE COUNTY.

FIG. 2.—PATAPSCO VALLEY AT ILCHESTER, ON BALTIMORE AND OHIO RAILROAD.

of Coastal Plain streams, cut down through the Coastal Plain and Newark covers and impressed themselves upon the underlying structures. They thus belong to the class of superimposed rivers. Examples of such drainage from other portions of the world have been cited above, but they are not lacking from districts nearer home. In Texas[1] streams and topography have been found which show signs of similar superposition from the blanket of the Coastal Plain sediments. In Connecticut[2] the lower course of the river of the same name departs at Middletown from an easy course along the Triassic sandstones, and turning to the southeast enters a deep gorge in the gneiss, which it follows to Long Island Sound at Saybrook. This aberrant position is attributed to superposition from the surface of a former northern extension of the Coastal Plain whose nearest representatives are now found on Long Island.

### GENERAL TOPOGRAPHIC HISTORY OF THE PIEDMONT PLATEAU.

Reviewing the topographic features of the Piedmont Plateau, the succession of events and the stages in the topographic evolution of the province may be briefly summarized as follows: After the cessation of those movements which folded the sediments of the western interior seas into the Appalachian mountain system and raised them higher than the eastern crystalline land areas whence the sediments had been derived, the Piedmont district was slightly depressed and long shallow bays were formed in which the muds and sands of the Newark formation were deposited. How much time this required cannot be ascertained; but long before the end of Jurassic time these sediments had been consolidated, the bays drained of their waters, and the strata uplifted and broken into a multitude of blocks. Volcanic action also had forced in between the strata sheets of heavy dark-colored lavas. Then came a long period of terrestial quiescence during which the broad, even expanse of the Schooley peneplain was stretched across the variously arranged rocks of the Piedmont and

[1] Tarr, R. S., "Origin of some Topographic Features of Central Texas," Amer. Jour. Sci. (3), 1890, xxxix, 306-310. "Superimposition of the Drainage in Central Texas," ibid., xl, 359-361.

[2] Kummel, H. B., "Some Rivers of Connecticut," Jour. of Geol., 1893, i, 371-393.

the Appalachian regions. This peneplain probably extended fifty to one hundred miles beyond its present eastern boundary. This period of quiet ceased in late Jurassic time, being brought to a close by a slight elevation which permitted the fashioning of small limestone valleys below the general surface of the eastern Piedmont portion. This elevation was of short duration and gave place to the strong eastward tilting which permitted the westward transgression of the upper Potomac formations and later groups.

After this the land oscillated up and down causing the series of submergences and elevations which are recorded in the various strata and unconformities of the Coastal Plain series. During most of these oscillations of the eastern portion, the plain beyond Parr's Ridge stood continuously above sea-level, and the rivers, steadily working on their valleys, reduced many of them very nearly to base-level, leaving the ridges and mountains between to indicate the former higher altitude of the country as a whole. As these base-leveled valleys were produced during Tertiary time the general plain to which they were reduced, now 500 feet above tide, is called the Tertiary peneplain. At the close of Tertiary time a movement of the lands bordering the west permitted the sea to rapidly transgress upon the Piedmont Plateau almost to its western limits.[1]

The blanket of soil, which had been produced by long exposure to the atmosphere, was rapidly and incompletely worked over into the Lafayette formation and spread out as a thin mantle of irregularly stratified gravels, sands and clays. Again a period of elevation and erosion came on, during which deep gorges were cut in the Piedmont Plateau by the streams which originated on the Lafayette surface. Large areas of Lafayette materials were stripped from the surface of the crystalline rocks and carried down into the stream valleys. Along the Monocacy valley this elevation initiated the cutting out of the second terrace, which lies below the upper floor or Tertiary peneplain level.

The post-Lafayette elevation and period of erosion was followed by a number of oscillations which are recorded in the various deposits

[1] Concerning the extent of this transgression, see chapter on the Coastal Plain, p. 77.

of Pleistocene age. Pleistocene time closed with a decided elevation of the Maryland Piedmont Plateau causing the streams to trench their valleys, and to cut narrow gorges in the underlying gneisses and other foundation rocks. Although the streams west of the Fall Line are still at work reducing their channels, the portions of their valleys which are east of this line have, after this elevation, in common with the Coastal Plain, been depressed and converted into estuaries.

## ECONOMIC PHYSIOGRAPHY.

In studying the Coastal Plain the physical features of that province were found to exert considerable control over the industries and habits of the people. The topography of the Piedmont Plateau has likewise influenced the settlements and the occupations of those who chose this region for their home.

### *Soils.*

The early settlers, having to raise all their food, naturally sought out the best locations for their broad farms and beautiful estates. On their arrival they found two general classes of farmlands.

The first class embraced the somewhat rolling but extensive tracts of the interstream upland areas. The soils were found to be good producers of corn, wheat and grass, and the surface not so rough as to make its cultivation forbiddingly difficult. The long continuous tracts of these interstream areas also made traveling easy as long as one stayed on the upland, while the stream valleys were shut in and narrow. For these reasons, probably, the various stately manor lands were laid out where the upland expanses were greatest; and the mansions surrounded by fine groves and broad fields were located on the most promising of the small plateaus. In the earlier days the crops from these broad upland farms were among the richest in the state and rivaled those of the Eastern Shore.

The second class of farmlands comprised the alluvial loams and sandy flood-plains along the streams. These lands are generally restricted in area, since the valley bottoms are usually narrow and limited in extent. Where streams have opened out lowlands on the marble and limestone lenses rich lands of considerable extent offer most favorable farm sites. The lands along the streams have the advantages of running water and good springs from the hillsides, they are not as well drained, however, as are the lands of the upland, and they are subject to damaging floods. Comparatively few settlers chose the valley lands at first.

A marked exception to the above rule is found in the Monocacy valley, where the farmlands are all located on the several benches and terraces leading down to the river or on the low bottomlands belonging to it. So little of the old upland is left that the conditions of occupation are quite different from those farther east.

*Streams.*

While the farming class were searching for good soils and favorable homestead sites, the manufacturers and millwrights were seeking favorable locations for mills, dams and flumes. The streams of the Piedmont Plateau yielded a great abundance of water-power, and soon mills dotted the valleys. Each section early came to be supplied with its grist mill, and in due time cotton mills were also built. These industries in time became of great importance. The flour mills are now generally abandoned, however, only a few of the most favorably situated ones having been able to maintain themselves against western competition. The cotton mills have held out much better, because it has not been until recent years that southern cotton has been spun and woven at home.

The water-power which the Piedmont streams furnish is not the only wealth which they bring to the state. The land movements during late geological time have caused the streams to trench their courses considerably, and in so doing have rendered accessible the building stones which were previously hidden beneath the surface. The granite now extensively quarried at Port Deposit would not be so easily obtained and shipped had not the Susquehanna river cut its deep gorge. The locations of the serpentine quarries of Harford county are determined to a greater or lesser extent by the streams which intersect the rock. A formerly important soapstone quarry on Winter run in the southeast corner of Carroll county was made possible only through the fact that the stream had there cut a deep gorge in a long band of steatitic serpentine. Along the Patapsco and Jones'

Falls many quarries of granite and gneiss have been located, because the stream gorges offered favorable openings or transportation facilities.

It is interesting, by way of contrast, to compare the different conditions under which the Cardiff-Delta slates are quarried. As no stream cuts across Slate Ridge in the vicinity of those two settlements, the quarries have been located along the summit and are worked entirely from above. This is the most difficult way to attack the slates, and as there is no natural drainage for the quarries, the water which is constantly accumulating in the pits greatly increases the cost of working.

*Lines of Communication.*

The valleys and ridges of the Piedmont Plateau furnish excellent examples of the way in which topographic features influence commerce and human activities.

One of the first acts of the early settlers of the Piedmont region was to lay out highways. These early roads were not always located advantageously with reference to the topography, but both the divides and the valleys were extensively employed. When the better turnpikes came to be built, however, they were almost without exception built along the divides. The reason for this was that fills and bridges were thereby avoided and better drained roadbeds, not subject to floods, were obtained. Radiating in all directions from Baltimore, these old pikes may be followed into almost every corner of the state, and their location on the more elevated ridges enables the traveler to obtain beautiful views of the richly wooded, rolling upland and tree-filled valleys.

With the advent of the canals and railroads more even grades were demanded and sought for. They were found by following the larger valleys.

The canals were built to overcome the obstructions to navigation which the Fall Line rapids occasioned, even in the larger streams such as the Susquehanna and the Potomac.

One of the early canals was the Susquehanna Canal, built along the east shore of the Susquehanna river in order to transport merchandise from the limits of navigation at Port Deposit northward along that stream to the Pennsylvania line. This canal has now wholly fallen into disuse.

Another early and successful canal was constructed around the Great Falls by the Potomac Company. To obtain the necessary water and the most favorable grades this channel, now part of the Chesapeake and Ohio Canal, was laid out along the north bank of the Potomac, taking advantage of the natural trenches cut by that river. This canal was long the cheapest and best means of transportation between the coal and wheat lands of Allegany county and tidewater.

Since the era of railway construction began every advantage has been taken of the topographic features of the country. The Baltimore and Ohio Railroad crossing the Piedmont Plateau from tidewater found an easy exit from the depression about Baltimore and a gentle though crooked grade to the crest of the divide by following up the South Branch of the Patapsco river to Mount Airy and then along the Monocacy drainage to Point of Rocks.

The Western Maryland Railroad striking north and then westward could not utilize the lower course of the North Branch of the Patapsco on account of its narrow valley and very crooked channel. By following the broad, well-graded valley of Gwynn's Falls (see Plate XIX, fig. 2), as far as Emory Grove, however, an easy descent was found into the more favorable upper course of the North Branch of the Patapsco and thence an easy grade led to the sag in the divide at Westminster. A branch of the Western Maryland road running north from Emory Grove follows the Gunpowder-Monocacy divide as far as Manchester.

The Northern Central Railway enters the state from the north by following down the main branch of the Big Gunpowder and does not leave this stream until at Phoenix Mills the broad marble lowlands about Cockeysville open out and offer an easy crossing to the valley and gorge of Jones' Falls, which it follows down to Baltimore from Lake Roland.

A striking example is afforded by the Baltimore and Lehigh Railway which takes advantage of the gorge of Deer creek to penetrate Rocky Ridge. Were it not for the aid thus rendered by the creek the engineers of the road would have been obliged to tunnel through the obstruction or else have gone a number of miles out of a direct course. Deer creek would not have been located across the quartzite and so could not have cut the gorge had it not accidentally taken this position while flowing on the Coastal Plain covering from which it was superimposed upon the quartzite. Besides the railway a county road also utilizes this gap and there are reasons to suppose that before the advent of the white man the Indians also used it as a thoroughfare.

In conclusion it appears that the topography has very materially controlled the settlement and economic development of the Piedmont Plateau by determining the location of the farms, the mills, and the railroads.

## The Appalachian Province.

### BOUNDARIES OF THE PROVINCE.

The Appalachian Province of Maryland embraces what is commonly known as Western Maryland. The eastern boundary of the province is formed by Catoctin mountain, while the western limits are artificially confined by the western boundary of the state, although topographically and structurally the province continues westward until it merges gradually into the lowlands of the Ohio drainage. To the north and south the topographic features of the province reach far beyond the limits of our state. The broad lowland of the Great Valley and the many parallel even-crested ridges with intervening valleys, which are so characteristic of the province, extend from central Alabama and Georgia northward through Maryland and then across Pennsylvania until they disappear in the plateau country of southern New York.

### *General Topographic Features.*

The topography of the Appalachian Province is more varied, more picturesque and grander than that of either of the other two provinces. In its eastern part the broad and somewhat serrated crests of the Blue Ridge and Catoctin mountains overlook the broad, gently rolling floor of the Cumberland or Hagerstown valley, which is watered by Antietam and Conococheague creeks, streams of some size that have sunk meandering trenches to depths of seventy-five or eighty feet below the general level of the valley floor.

Beyond the Great Valley may be seen the long, even crest of North Mountain. This strongly marked topographic feature is the most easterly of a series of long, parallel mountains running northeast-southwest and alternating with long, narrow valleys. These ridges and valleys are the chief topographic features of the district between the Great Valley and Dan's Mountain west of Cumberland. They are termed the Appalachian Ridges and have been classed under that name as one of the sub-provinces of the Appalachian Province on the Outline Map, Plate III. Beyond these ridges, which gradually increase in height westward, the general surface spreads out as an extensive upland or plateau with an average elevation of 2500 feet, from which low parallel ranges of mountains rise.

## THE STRUCTURE OF THE PROVINCE.

### *Present Structure.*

In describing the Piedmont Plateau it was pointed out that the topography was so closely related to the geology that a map could be made showing the amount of topographic influence which the various formations had exerted, although strongly influenced by the covering of Coastal Plain sediments. The Appalachian Province still more strikingly shows this relationship, since the winds, rains and rivers have been at work for ages etching out the mountains and valleys along the lines determined by the structure of the country. The hills and the mountains all indicate by their parallel arrangement and N.E.-S.W. trend that the resistant rocks cross the state in the same direction, while the valleys tell the same story about the location of the less resistant formations. Such an arrangement of ridges and valleys as characterizes the Appalachian Province might indicate a structure similar to that shown in Fig. 5, but an examination of the attitudes of the various strata shows that the actual structure is as reproduced elsewhere.[1] This cut shows that the strata have been

[1] Md. Geol. Surv. Rept., vol. ii, 1898, p. 59, fig. 6.

thrown into folds whereby at certain points hard resistant conglomerates and sandstones have been brought to the surface, while at other points they have been thrust deep down and only the more yielding rocks above them appear. Many of the smaller ridges and even elevations such as Wills Mountain, mark lines along which some hard, resistant stratum has been arched up. Such ridges have their general cross profile determined by the arched strata which maintain them. Other prominent ranges, such as the Blue Ridge, owe the elevated positions of their resistant rocks to great dislocations along which the rocks have been thrust up above their earlier positions.

Between the ridge-forming folds or anticlines there were originally valley-forming troughs or synclines, in which it is probable that the rains gathered and formed streams which would be classed as consequent. To-day a number of small streams occupy similar positions among the ridges and mountains of Washington county. It is not at all likely, however, that these present streams have inherited their courses from consequent ancestors. On the contrary, since the synclinal troughs are occupied by yielding shales, it is much more likely that the streams took courses immediately above their present locations during the time when this whole district was being reduced to the general surface of the Schooley or Cretaceous peneplain. During that period of erosion the summits of the present hard ridges appear to have acted as guides directing the streams to develop along the more easily eroded strata of the synclines. In many cases the arches of hard rock originally rose so high above sea-level that they were truncated by the broad, gentle surface of the peneplain, as it was gradually extended across the folds. The domes of rock were thus completely unroofed and their cores of softer rocks became exposed to the attacks of the elements. Guided by these easier paths, certain rivers extended their courses, not along constructional troughs or synclines, but along the axial lines of the arches or anticlines. Along the axis of a comparatively broad flat anticline in Garrett county the two branches of the Savage river have opened the broad depression lying between Savage and Meadow mountains.

### *Original Structure.*

The gradual change from the much disturbed strata of Washington and Allegany counties to the almost horizontal arrangement of the same strata in the plateau districts of Garrett county and of West Virginia, serves to remind the observer of the original positions of these beds. The successive layers of finer and coarser materials, the remains of animals and plants, and the close resemblance between many members of the series and various deposits which may be seen forming to-day, all point to the conclusion that these strata were deposited in succession over the floor of some very ancient sea. These strata, now so crumpled and folded, must have originally been almost horizontally disposed, just as any series of layers of mud and sand at the bottom of a pond may be seen to have arranged themselves when, the pond being drained, a ditch is cut across its old bed. All the present dislocations of those ancient strata are the products of folding and faulting under compression, which came after the rocks were laid down as horizontal beds of clays, sands and calcareous muds at the bottom of the interior Paleozoic sea.

### *The Appalachian and the Coastal Plain Structures Compared.*

The strata now forming the Appalachians were deposited in more or less close proximity to a shore or coast which lay along the eastern limits of that ancient sea. The general location of this ancient land area, as indicated by the sediments derived from it, seems to have been in the district now occupied by the eastern Piedmont Plateau and western Coastal Plain provinces. In the period during which the Paleozoic strata were deposited this province was a more or less lofty land area, whose rivers, flowing westward, carried down large quantities of detritus to the sea. As the amount of materials thus transferred from land to sea floor increased, the sea itself would have been largely filled up had not the lands beneath the sea gradually subsided. In this way there was accumulated the great series of Paleozoic strata which stretched far westward from the coast of that time.

If now the strata deposited in this Paleozoic sea are compared prior to their dislocation, with the present Coastal Plain series, several points of resemblance, particularly as regards origins and relations to the mainland, may be pointed out. Both the Paleozoic and the Mesozoic-Cenozoic sediments were deposited in seas often comparatively shallow, but which, although constantly filling with new materials, were also for a while gradually deepening, thus continuing the period of deposition. Both series of sediments were derived not only from areas immediately bordering the respective basins of deposition, but also in part from precisely the same region, namely, the Piedmont district. These comparisons show that during long periods in geological history the Piedmont region has been supplied with a Coastal Plain.

## TOPOGRAPHIC SUBPROVINCES.

It is clear from the general description of the Appalachian Province given above that a four-fold subdivision is possible on the basis of the topographic types represented. These subdivisions from east to west may be designated as The Blue Ridge, The Great Valley, The Alleghany Ridges and The Alleghany Plateau.

### *The Blue Ridge.*[1]

The physiographic subprovince here designated by the name of the Blue Ridge includes the Blue Ridge proper, the Catoctin mountain and the district lying between them. Blue Ridge proper, which forms the western boundary of the subprovince, is a long, straight ridge with slightly uneven and knobby crest maintaining an average elevation of 2000 feet above tide level. It starts in Pennsylvania as a portion of South Mountain, passes southward through Maryland and, after declining somewhat on each side of the Potomac gorge at Harpers Ferry, rises again in Virginia to a somewhat lesser elevation. That portion which lies within the limits of Maryland owes its crestline altitudes to the superior resistance of the Lower Cambrian or Weverton sandstone which reached its present elevation partly as the result of a great overthrust fault, partly through more recent elevations of the whole of the Appalachian district.

[1] The names applied to this topographic unit vary in the different states traversed. In Pennsylvania the entire range is *called* South Mountain, in Maryland, South Mountain or the Blue Ridge, and south of the Potomac the Blue Ridge. Keith has applied the general term Catoctin Belt.

Although subsequent denudation has carved numerous scars and slight sags in the crest of the Blue Ridge, except for the narrow defile of a small branch of the Antietam creek debouching at Leitersburg, the Ridge presents an unbroken crest from Gettysburg Gap on the north to the deep gorge of the Potomac at Harpers Ferry. The western slope of the Blue Ridge Divide has the greater relief since its summit rises about 1500 feet from the level of the Cumberland or Hagerstown valley. The contours of this slope are generally precipitous along its upper zones. Over the lower portion they become much softened, however, and grade into low, rounded foot-hills which mark the outcrop of a band of fissile shales, Harper's shale, lying between the quartzite and the limestone, Shenandoah. The eastern slope of the South Mountain, since this is the direction in which the capping sandstone dips, is much milder than the western face. It also presents less boldness of relief because the contrast between the sandstone and the volcanic rocks lying against it on the east is much less pronounced than is that between the sandstone and the limestone or the shales of the Hagerstown valley.

East of the Blue Ridge proper, and almost parallel with it, runs the straight and slightly undulating ridge called Catoctin mountain, which forms the eastern boundary of the Blue Ridge subprovince. Its prominence is due to the greater resistance of the heavy Cambrian quartzite, which has withstood the attacks of the elements more successfully than the rocks on either flank. Again it is with the Catoctin, as with the Blue mountain, that that slope, which descends to the yielding rocks of the broad valley lowland, is the longer and the more precipitous, while the opposite slope is the milder and the shorter. Here, however, the valley lowland is that of the Frederick or Monocacy valley carved out on the Frederick limestone and the Newark formation. This lies to the east of the ridge, while the shorter and milder decline forms the western slope.

The continuity of the ridge is interrupted only twice within Maryland. Both gaps are in the northern portion of the crest and are cut by the two tributaries of the Monocacy between which is situated the town of Thurmont. The more northern of these streams is the larger and has cut such a deep gap through the crest that it serves for the passage of the Western Maryland railroad on its way across the range.

Turning now to the valley included between the two crests just described it is found that this portion of the Blue Ridge subprovince has a number of peculiar and interesting features. It attains its best marked and most characteristic development in the southern portion of the district, in the drainage basin of the Catoctin creek, and is less characteristically a valley in the northern half of the area which is drained by the Monocacy and Antietam tributaries. In spite of the fact that nearly half of the drainage basin of Catoctin creek is underlain by igneous rocks, like granite and quartz porphyry, and the remainder by the still more resistant Catoctin schist, the stream has reduced a considerable portion of its basin almost to a base-levelled state during a geologically recent period. Starting with an average elevation of about 500 feet over that portion of the valley lying along the Potomac the old valley floor, now appearing as even-topped remnants between the streams, may be traced northward a little beyond Myersville, where it has reached an elevation of about 750 feet. A considerable part of this rise is accomplished within the last ten miles, where it is accompanied by a decreasing degree of regularity in the character of the old valley surface. This gradual change in perfection of modelling is what would naturally be found to exist over the up-stream portion of an old valley, since the lower portions of a stream's course are always found to be reduced more perfectly and uniformly than are its up-stream limits. Beyond Myersville the traces of this old valley floor are quite lost if the feature ever existed there. Below the more or less even surface of what may be called the 500 feet level, the Catoctin and its tributaries have incised their channels to depths up to a hundred feet, according as they are farther from or nearer to the present local base level, the channel of the Potomac river. The cross-sections of the gorges, as well as their depth below the old level, are indicative of their relative locations. Beginning with the narrow V-shaped ravines of the most distant and youngest branches, the gorges gradually assume a cross-section shaped like a U. This form is characteristic of the lower course of the main stream and of the larger branches. It indicates that the streams have progressed beyond the stage in which vertical down-cutting is predominant, and have reached a point where the weathering of the canyon walls furnishes material somewhat in excess of the stream's ability to transport it. Above the general 500 feet level there remain a few areas not wholly reduced. These are more numerous along the sides and particularly at the head of the basin where they gradually merge with that portion of the area which never was reduced to the 500 feet plain.

The northern portion of this district, lying between the crests of South Mountain and Catoctin, seems never to have been reduced to such a valley lowland as formerly existed along Catoctin creek. The reason for this is evident. This portion of the area is drained chiefly by four or five streams already mentioned, all of which have to cut their way out across the refractory and practically insoluble quartzite before they can begin to work on the almost equally resistant epidote-schist. In contrast to these difficulties stand the conditions governing the Catoctin creek drainage. This system is largely employed in draining the areas of granitic rocks and the quartz porphyries, both of which, on account of the considerable percentages of feldspar in them, yield more readily to the solvent action[1] of the ground water. Owing to this peculiarity of the various rocks, Catoctin creek which flows directly into the Potomac after traversing the granitic rocks has been able, both in the past and the present, to reduce the lower portion of its channel with comparative ease, and so retain a decided advantage over its opponents on the north. The combined action of the resistant rocks to the north, and the superior powers thus possessed by the headwaters of Catoctin creek working up from the south has, so far, resulted in confining the drainage of the northern streams within comparatively narrow bounds. Although the volumes of the latter streams have thus been limited to such meagre proportions, small subsequent streams and valleys along the comparatively yielding quartz-porphyries have been developed, and to-day there may be seen green, level-floored, narrow valleys wind-

[1] Keith, A., U. S. Geol. Surv., 14th Ann. Report, pp. 310, 378.

FIG. 1.—THE POTOMAC AT WILLIAMSPORT, ON WESTERN MARYLAND RAILROAD.

FIG. 2.—VIEW FROM MARYLAND HEIGHTS, SHOWING "THE GREAT VALLEY" IN THE DISTANCE.

ing in and out among numerous bluntly conical hills or long ridges. Below these valleys, particularly near the mountain fronts, the torrent-like streams have often cut steep, wild gorges.

*The Greater Appalachian Valley.*

The Greater Appalachian Valley,[1] or as it is sometimes called, the Greater Valley, embraces all the country lying between the Blue Ridge on the east and Dan's Mountain or Alleghany Front on the west, and thus has a width of about 73 miles. As has been noticed above, the Greater Valley admits of a two-fold division into the Great or Cumberland Valley on the east and the zone of Alleghany ridges on the west.

*The Great or Cumberland Valley* is the rather broad, even depression lying between the Blue Ridge on the east and North Mountain on the west. This broad, fertile valley, sometimes known as the Hagerstown Valley where it passes through Maryland, is a marked, topographic feature throughout the whole extent of the Appalachian province. The sharp contrast which it makes with the surrounding ridges is well shown by the model which was constructed for the Cumberland Valley Railroad and is here reproduced as Plate XIV.

The principal topographic feature of the Great Valley is its broad, gently rolling floor. Although this floor is now much cut up by minor drainage lines, its formerly almost level surface has given the present hills very strikingly accordant elevations. So nearly coincident are the various heights that, if a flat board floor could be laid across the valley it would be supported by almost every hill and would have an altitude of about six hundred feet above sea-level. Long divides with broad tops maintain this average elevation over considerable distances, and are generally occupied by highways. There is a slight descent from the northern boundary of the state to an elevation of from 500 to 550 feet along the Potomac, which brings this former plain into relation with the plain along the Catoctin creek and the Monocacy river. Southward from the Potomac, however, this plain rises as it follows up the Shenandoah valley, finally reaching a maximum elevation of 1700 feet in southern Virginia. The pho-

[1] B. Willis, The Physiography of the United States, 1896, p. 169.

tograph forming Plate XIII, fig. 2, illustrates the general character of this valley floor in the vicinity of the Potomac.

The principal streams draining the Maryland section of the Great Valley are Antietam and Conococheague creeks, both of which rise in Pennsylvania and flow southward through Maryland to the Potomac. The valleys of these streams are deep, narrow and steep-sided, that of Conococheague creek being particularly gorge-like in character. The streams themselves are rather rapid and have not yet reduced their channels to even grades, as is shown by the low ledges of shale or even limestone which sometimes interrupt their flow. The courses of the channels are tortuous, often quite meandering, and the turns and twists of the channels are always followed by the gorge walls. This fact indicates that the streams originated their meanderings on the flood-plains which accompanied them when the present dissected valley floor stood at a lower elevation and these streams flowed upon its continuous surface. As the area was elevated the streams began to cut down along their courses, always keeping a little behind the Potomac as it deepened its channel. Thus the winding courses which the streams followed on their earlier flood-plains became impressed upon the limestone and shale beneath, and these more resistant rocks still retain the streams in their old courses which are described as *inherited* or *superimposed.*

The general characteristics of *the Alleghany Ridges* have already been briefly sketched. Several of these ridges are due to the uparching of resistant sandstones which have withstood the attacks of the elements, while the yielding rocks which covered them have given way. The best examples of such prominences are found in Wills Mountain, Martin's Ridge, Warrior's Ridge and North Mountain. The dome of the arch in the latter case has been partly removed, however, and the yielding shales beneath which were formerly protected are now rapidly giving way. There is thus forming a shallow and elevated valley along the axis of the uplift. All of these mountains rise very nearly if not quite to the 2000 foot level.

Other crests, such as those of Town Hill, Sideling Hill and Tonoloway Hill, fail to reach this height by about five hundred feet.

They owe their elevation to the fact that, in a number of cases, the Carboniferous conglomerate or sandstone was depressed below the general level of the Schooley peneplain, and thus escaped being worn away during the production of that feature. Subsequent elevation and erosion have removed the softer rocks, which are then exposed by the unroofing of the arches or anticlines and these small synclinal remnants of the hard sandstones now stand out in relief as protecting caps to the yielding strata just beneath them. Thus what was originally a series of constructional synclinal valleys has been converted into a set of parallel, even-crested ridges with synclinal summits.

Between these mountains and ridges comparatively broad, even-floored valleys were at one time carved out by the streams which had breached the anticlinal arches during the Mesozoic era. For so long a time did the land stay at rest after the elevation of the Schooley peneplain that these streams reduced their valleys to very gentle slopes, even far back in among the ridges. Sufficient time, however, was not allowed for their reduction of the ridges, also, as was the case during the preceding cycle. It was at this time that the level floor of the Great Valley was produced, the general surface of which can be followed in and out among these western ridges. This generally even and accordant surface is often referred to as the Shenandoah Plain, because it is so typically developed over the yielding rocks of the Shenandoah valley. Having been developed only in the vicinity of the streams, the Shenandoah Plain is found to rise gradually as it extends towards the headwaters of the various mountain streams of the central district. The general elevation, however, is found to be somewhat greater and the inclination of the surface steeper than would be the case if due simply to the normal stream slope of the region. These features are believed to be due to a general and unequal elevation of the land after the Shenandoah Plain had been developed. This elevation, or more strictly speaking, warping, was greatest along a northeast-southwest axis located near the eastern boundary of the Alleghany Plateau, and also along a minor axis running southwestward from southern Virginia and West Virginia, the influence of which was extended as far northward as Maryland and eastward to the Atlantic coast line, affecting to some extent the district of the Alleghany ridges.[1]

This warping of the Shenandoah Plain exerted a marked influence upon the development of the well-adjusted streams of the Appalachian district which, at the close of the period of denudation, were meandering over comparatively broad flood-plains. The elevation which succeeded the period of denudation revived the activities of the streams, and they rapidly deepened their channels, cutting narrow winding courses, taken from their former directions on the Shenandoah Plain. Continued denudation has now worn away considerable portions of the inter-montane region, so that its general surface can be traced only in the long, flat inter-stream areas and the rounded crests of those hills which rise to the general level of the plain.

Among the most characteristic remnants of this formerly extensive surface may be mentioned Shriver's Ridge, with an elevation of 1071 feet, the northern spur of Knobbly Mountain across the Potomac river with an elevation of 1115 feet, the heights northeast of Cumberland with an average elevation of something over 1000 feet, and the broad, dissected district extending northward from Old Town, which is drained by Big Spring run and Town Creek, with an average elevation of about 900 feet. The character of the gorges which the streams have cut below the uplifted Shenandoah Plain clearly shows that the rate of elevation was not uniform. At least three distinct terraces can be made out along the banks of the Potomac in the vicinity of Cumberland. Each terrace indicates a period of temporary quiescence for the land, during which the stream was able to expend some of its energy in the horizontal cutting and widening of its channel; while each slope from a higher to a lower terrace indicates renewed activity in vertical down-cutting. The two upper terraces belong to the class of *stream-cut terraces*, as is shown by the fact that their almost horizontal tops are bevelled across the upturned shales. Only a very thin layer of scattered cobbles and gravels is found on either terrace. The lower terrace is so heavily

[1] Hayes, C. W., and Campbell, M. R., Nat'l Geog. Magazine, vol. vi, 1894, plate 6.


VIEW OF MODEL OF THE BLUE RIDGE AND THE GREAT VALLEY, TRAVERSED BY THE CUMBERLAND VALLEY, WESTERN MARYLAND, BALTIMORE AND OHIO AND NORFOLK AND WESTERN RAILROADS.

(PUBLISHED BY PERMISSION CUMBERLAND VALLEY RAILROAD.)

covered with river deposits of sand, gravel and boulders that it is difficult to say whether it is a *cut* or a *built* terrace or a combination of both. These terraces, particularly the two lower ones, may be followed down the Potomac beyond Harpers Ferry running in and out of the stream valleys which join that river from either side and gradually declining in elevation. Up-stream they have been traced as far as Keyser and undoubtedly extend a considerable distance further. Attempts have been made [1] to correlate these terraces with contemporaneous epochs of deposition contained within the Coastal Plain series, but very recent work in that group of deposits by the New Jersey and Maryland surveys has so altered former conceptions of stratigraphic sequences and conditions of deposition that it seems best for the present at least not to attempt a statement regarding the stratigraphic equivalents of these features.

### *The Alleghany Plateau.*

The Alleghany Plateau extends from northern central Alabama, where it is known as the Cumberland Plateau or tableland, northward and eastward through Tennessee, Kentucky, Virginia, West Virginia, Maryland and Pennsylvania into New York, where it forms the high lands covering the southern half of the state from the Catskills to Lake Erie. This plateau, which preserves, in its general level, the largest continuous areas of the Jura-cretaceous, or Schooley peneplain, is not characterized by a broad, unbroken expanse, but has been so deeply dissected that only the even crests of isolated ridges remain to indicate the former extent of the plateau. Standing on some lofty central point, such as the crest of Keyser's Ridge in Garrett county, one sees all about these long level-topped crests which seem to rise very nearly to the same general height, although there is a gradual decrease in elevation northward and eastward from the district between Savage Mountain and Keyser's Ridge. The long ridges are arranged in almost parallel ranks and follow the broad curves of the Appalachian system, while their even crests are the

[1] McGee, W J, "The Terraces of the Potomac Valley," *The Evening Star*, Washington, June 20th, 1885.

Keith, A., U. S. Geological Survey, 14th Ann. Report, 1892-93, pp. 285 et seq.

present representatives of that broad peneplain which has already been so often referred to in dealing with the eastern portions of Maryland. The most representative elevations of this peneplain are found in Savage Mountain, which has an altitude of about 3000 feet in Keyser's Ridge and Negro Mountain, with elevations of 3000 feet, in Winding Ridge 3000 feet, and Hoop Pole Ridge 2800 feet. These elevations are the culmination of the westward rise of the Schooley peneplain in the latitude of Maryland. Farther westward the general surface gradually declines to the Ohio and the Mississippi rivers. Within the Maryland portion of the plateau the strata are still gently folded, so that the extension across them of the old peneplain surface here also resulted in the removal of several rock domes. Thus, while the land was being reduced to very mild topographic forms, the way was being prepared for the easy carving out of lofty mountain ranges during a subsequent time. As a result of the elevations which have taken place since the Schooley peneplain was produced, the streams which had developed on that surface, and whose courses were adjusted to its underlying structure, have deepened their valleys very considerably. There were other streams, however, which, although they occupied courses located on yielding rocks, had carved their valleys out along synclinal axes and have not, since their elevation, materially deepened their valleys.

There are thus seen to be two classes of valleys and streams within the boundaries of the Maryland portion of the Plateau, one class has synclinal or consequent streams and valleys, the other class embraces the subsequent or anticlinal streams. The characters of the valleys of these two classes are quite as distinct as their relations to the structure. The subsequent streams have developed their courses generally along Jennings and Hampshire shales, which formed the cores of anticlines whose domes were the resistant Pocono sandstone. The elevation which interrupted further development of the Schooley peneplain gave all these streams increased activity and they began to actively reduce their valleys to the new base-level.

To-day the new valley-floors thus produced may still be seen as flat-topped hills of Hampshire and Jennings shales bounded by steep and often precipitous cliffs which are capped by rocky crags of Pocono sandstone. Perhaps the largest area covered by this surface of denudation is to be found in the vicinity of Accident. This town is located near the center of a broad amphitheater, whose boundaries are the curving Pocono-capped crests of Winding and Keyser's ridges, and whose floor is a very gently rolling surface, large portions of which remain over the inter-stream areas. This is the old floor produced just after the elevation of the Schooley peneplain. Numerous disconnected areas along the northwestern flanks of the Savage river valley also preserve this surface. Turning to those streams which pursued consequent or synclinal courses, it appears that instead of occupying deep valleys with steep bounding slopes, their valleys are comparatively shallow and stand at higher levels than do the subsequent valleys. These consequent valleys are now lifted high above the other streams and present very slight contrasts in relief as compared with the other streams of the Plateau. The best example of this class of streams and valleys is found in the valley of the Castleman river. This stream is located on the portion of the Fairfax formation, or Barren Measures, which reposes in the synclinal basin between Meadow and Negro mountains. The valley is very broad and comparatively shallow, especially at the southwestern end of the syncline, and there is no sudden break in the slope from the crests of the two limiting mountains to the axis of the valley. The reason why the streams draining such valleys as that of the Castleman river have never been able to reduce those valleys successfully is due to the fact that the whole valley is floored with a resistant conglomerate or sandstone, which must all be removed before the mountain can be lowered. They are hemmed about by the same hard stratum, and the streams which have to cross it in order to leave the valley cannot remove the core of the anticline below the level to which they have cut down their outlet. It is, however, a much easier task to cut a gorge through a narrow ridge of the sandstone than it is to remove a broad, almost flat sheet of the same rock. Therefore, streams like the Savage have carved deeper and more sharply bounded valleys than have such rivers as the Castleman.

Just here it may not be amiss to refer to those broad, wholly enclosed valleys whose meandering streams are often bordered by rather marshy ground. Such valleys are known in Garrett county as *Glades*, while any valley which has steep bounding slopes and slightly marshy flood-plain is called "glady country." These poorly drained areas are calculated to attract attention in a district where the sharp relief of the country in general insures unusually well-drained soils. To one familiar with the poor drainage of the glaciated districts of the United States, glaciation [1] at once offers itself as an explanation of this topography. There are, however, none of the other signs of glaciation, such as transported boulders, striated ledges or morainic material. Moreover, it is possible to adequately explain the Glade Country by appealing to processes acting there at present and during the past. The following explanation, based on recent geological studies in the Glade districts, is offered by Mr. A. C. McLaughlin of the Maryland Geological Survey.

The typical Glades of Maryland are located on the strip of Jennings and Hampshire shales which lies between Backbone mountain and Hoop Pole Ridge in the vicinity of Oakland and Deer Park. This broad, gently rolling valley is drained by two rather sluggish streams known as North Glade run and Green Glade run, both of which unite beyond Hoop Pole Ridge to form Deer creek, a tributary of the Youghiogheny. Hoop Pole Ridge is a monoclinical ridge of Pocono sandstone which offers considerable resistance to erosion and has retarded both of the streams crossing it. While thus retarded at the edge of the Glades by this sandstone ledge, the headwaters of these streams have been working on the yielding shales until they have been reduced very considerably, in fact, quite to the level of the stream crossing on the sandstone. The stream grades are now so flat here that they cannot carry away the debris washed by the rains from the low shale hills. The result is that immediately along the streams the accumulation of alluvium has been so rapid that the stream is slightly choked and has thus become marshy. The Glades therefore are simply a well-reduced local base-level plain determined by the marked contrast between the yielding shale and the investing

[1] Gibbes, Geo., The Glades of Maryland, Amer. Nat., vii, 1873, p. 636.

barrier of resistant sandstone. It might be added that possibly the inability of the two streams to remove the alluvium may be due to decreased volumes, resulting from recent captures by the headwaters of the Savage or the Youghiogheny rivers, both of which have tributaries on the shales in the immediate vicinity of the Glades.

So far the Maryland streams of the Alleghany Plateau have been considered from their purely local relations. It is interesting to consider briefly their general relations to the broad structural features of the region. From this point of view also there are two classes of streams here; first, those which flow westward down the general dip of the strata to the Ohio, and second, those which flow eastward against the general dip to the Atlantic. The Youghiogheny and Castleman rivers take out all the Ohio drainage, while the Savage and the North Branch of the Potomac lead off the waters which flow into the Atlantic. It has already been pointed out that the whole Appalachian district formerly bore the relation of a coastal plain to a land area lying somewhere to the east. In view of this fact the rivers should naturally all flow westward down the inclination of the strata towards the old sea. As a matter of fact, only the Youghiogheny and the Castleman approach to this arrangement, while the Potomac and its tributary, the Savage, go in directly the opposite direction. They even do more, for they cut across what we can see of that old land area and empty into the Atlantic at a point where formerly there may have been high hills. To explain this anomalous course of the Potomac is one of the larger and more difficult problems for the physiographers of the Atlantic slope to solve.

### GENERAL TOPOGRAPHIC HISTORY OF THE PROVINCE.

The topographic history of the Appalachian Province may be briefly summed up as follows. The Province originated as a coastal plain along the western shores of some ancient land area, part of which may be represented in the ancient crystallines of the Piedmont Plateau. Probably shortly before the close of the Paleozoic this coastal plain was elevated and deeply folded in its eastern portion by powerful compression. This elevated and corrugated coastal plain then suffered a partial reversal of its westward flowing drainage, and remaining for a great length of time in a quiescent state, was so far reduced by erosion as to present the features of advanced topographic maturity and perhaps even become a peneplain. This period of repose was closed by a decided warping of the new surface that raised it to an elevation of about 2000 feet in Western Maryland, but only to about 300 feet in the central portion of the state. Then followed another period of repose during which the Shenandoah Plain was carved out. Finally a series of elevations at irregular intervals has warped the two plains, still further bringing the Schooley peneplain level to altitudes of 3000 feet in the western and 500 to 800 in the central section of the state, while the Shenandoah Plain stands at 1000 feet to 1500 feet in the west and 500 feet in the east. The latest elevations have caused the streams to cut below the level of the Shenandoah Plain a series of steep, terraced gorges that they are still deepening.

## ECONOMIC PHYSIOGRAPHY OF THE PROVINCE.

### *Lines of Communication.*

The obstacles offered by the successive parallel ridges of the Appalachian province delayed the westward movement of the population in colonial days and restricted the east and west lines of travel to the valleys of the Potomac, the Susquehanna, and the James. The earliest inhabitants found these natural highways already selected as the lines of communication between the distant parts of the great Indian Confederacy, and accepted the experience of the aborigines by building their roads along the same lines.

As the population of the western portions of the state increased the demand for more perfect highways became urgent, so that before the end of the eighteenth century several well-defined lines of travel had been established between the tidewater regions along the Atlantic and the Ohio drainage. The Cumberland road extended from Washington to Cumberland via Hagerstown and Hancock, and thus followed the line of easiest travel along the valleys and across the divides at their lowest points. Beyond Cumberland the road was extended across Big Savage mountain and the Alleghany Plateau, keeping on the divide between the Potomac and Youghiogheny until it entered

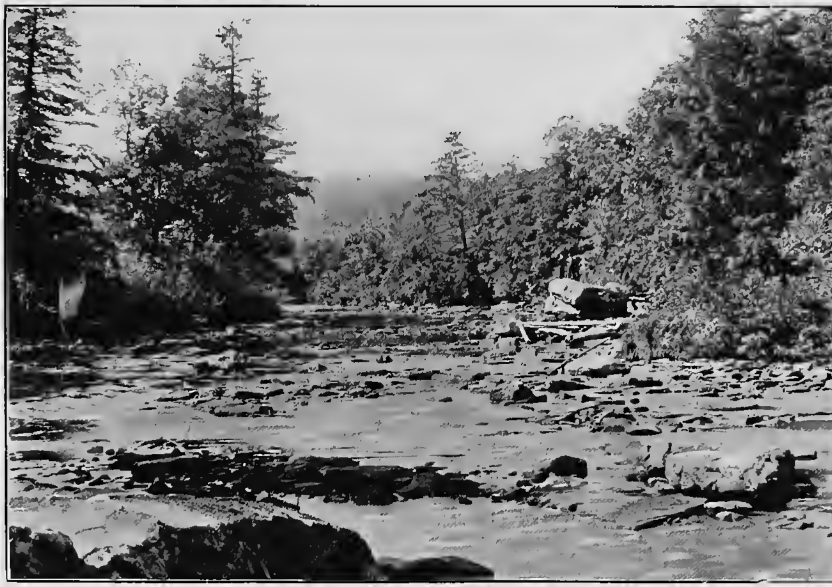


FIG. 1.—THE YOUGHIOGHENY NEAR OAKLAND.

FIG. 2.—THE YOUGHIOGHENY AT FRIENDSVILLE.

the valley of the latter, which it followed to the Monongahela, and thence down stream to Pittsburg.

Later the promoters of the Chesapeake and Ohio Canal gained the right of way up the Potomac valley, which is followed to Cumberland. The course of the Potomac at Harpers Ferry and Point of Rocks offered the easiest means of communication across the Blue Ridge district, and when once occupied the Chesapeake and Ohio Canal effectually stopped the westward progress of the Baltimore and Ohio Railroad along the same route until a compromise was effected in 1832. West of Cumberland the railroads crossing the state follow the valleys of the rivers, utilizing the courses of the Potomac river, Wills creek, Georges creek, Jennings run, the Savage river, and the Youghiogheny river.

### *Natural Resources.*

The resources of the Appalachians are varied and valuable. The early settlers found the mountains clothed with dense forests of pine and hard wood, but they lacked the means for transporting the lumber to a ready market. Even now with a canal and several railroads the cost of hauling from the forest to the point of shipment is so great as seriously to reduce the profits of the lumbering trade.

The many varieties of soils in the Appalachians are closely related to the geological formations, and their distribution is clearly influenced by the geological structure. Since most of the higher hills and sharp ridges are due to the presence of heavy beds of siliceous sandstone, the soils of the upper slopes are generally sandy and poor. Beneath these strata come beds of shales which are sometimes calcareous, so that the lower slopes, hills and *subsequent* valleys contain soils which, while somewhat stony, give fair yields in wheat, corn, etc.

The Great Valley, with its rich limestone soil and easy means of access from the north and south, forms a broad band of the most fertile lands in the state. If it had not been for the re-elevation of the Shenandoah plain this district would be most favorable to farming. As it is, the rolling surface and steep valley slopes are somewhat difficult to till with ease. The land is so rich, however, that the whole stretch of the valley is or might be under cultivation.

The chief sources of mineral wealth in the province are the deposits of coal, iron and cement rock. The coal beds are the remnants of larger areas preserved by their depression below the limits of erosion during the formation of the Schooley peneplain. They have proved of inestimable value to citizens of the state. The Clinton iron ores were formerly very valuable, but in the present state of the iron market they are of relatively little importance. The cement rock is obtained from certain portions of the Silurian limestones and is the basis of a growing industry. The exposures are favorably situated along the lines of travel, so that the mills have every advantage for the shipment of their product.

### *Inhabitants.*

The physiography, industries and resources of the Appalachian province have strongly influenced the character and occupation of the inhabitants, who may be grouped into several well-marked classes. In the higher more rugged and less populated portions of the area are the mountaineers, who gain their livelihood by lumbering and desultory farming. Gathered about the rich deposits of coal, iron ore and cement are miners, who are occupied almost exclusively in the extraction of wealth from the underlying rocks. They present a class of marked characteristics in education, training, religion and nationality. The valleys between the mountains, especially the Great Valley, and the larger more level areas of the glades, furnish incentive and opportunity for farming communities, which are reasonably well recompensed for their efforts in the tilling of the soil. In the cities and larger towns are concentrated those who serve as distributing agents for the products of the land and the necessities of the inhabitants.

## The Development of the Streams of the Piedmont Plateau.

### INTRODUCTORY REMARKS.

In 1888 Mr. W J McGee published a series of papers[1] on the earlier members of the Coastal Plain series, in which he interpreted

[1] McGee, W J, Three Formations of the Middle Atlantic Slope, Amer. Jour. Sci. (3), vol. xxxv, 1888, pp. 120, 328, 367, 448.

the geographic and topographic history of the regions by means of the sedimentary records. In this series he makes the statement[1] that "the former westward extension of the [Potomac] formation can be reliably inferred from the topographic configuration of the Piedmont region, the western part of which has a drainage evidently determined by lateral heterogeneity of the vertically bedded terrane and a characteristic topography resulting therefrom, while the eastern part has a drainage independent of the varying obduracy of the terrane and therefore evidently superimposed by a formation (which could only have been the Potomac) now generally removed by erosion." This statement is based on some work done several years previously upon the geology about the mouth of the Susquehanna river.[2] In this paper an epigenetic or superimposed origin for the streams of the eastern portion of the Piedmont Plateau was first proposed. As McGee did not give much detailed evidence in favor of this view, the writer undertook in 1895-96 the collection of details which are essential to the determination of its correctness. The purpose of this chapter is to set forth the results of the study thus inaugurated.

In 1889 W. M. Davis,[3] in his study of the Pennsylvania drainage, suggested that the discordant position of the lower course of the Susquehanna might be explained by supposing superimposition from a flood-plain contemporary and coextensive with the Potomac formation. Later in studying the rivers of New Jersey[4] he came to the conclusion that the locations of several small streams across the trap ridges of First and Second mountains were due to superimposition from a westward extension of the Coastal Plain sediments.

Only one other investigation of this nature has been conducted on the streams near Maryland. Miss Bascom[5] in 1897 published a short account of some discordant drainage near Philadelphia which is ex-

[1] Op. cit., pp. 133-134.

[2] McGee, W J, The Geology of the Head of Chesapeake Bay, U. S. Geol. Surv., VII Ann. Rept., 1885-86, pp. 545-644.

[3] Davis, W. M., The Rivers and Valleys of Pennsylvania, Natl. Geog. Mag., vol. i, 1889, pp. 241-242.

[4] Davis, W. M., The Rivers of Northern New Jersey, Natl. Geog. Mag., vol. ii, 1890, p. 99.

[5] Bascom, F., The Relations of the Streams in the Neighborhood of Philadelphia to the Bryn Mawr Gravel, Amer. Geol., vol. xix, 1897, pp. 50-57.

plained by superimposition from the cover of Potomac clays and gravels.

Beyond the limits of the Middle Atlantic Slope one or two important river studies have been executed which have some bearing on the Maryland problems. In 1890 R. S. Tarr[1] reported cases of streams in Texas which were superimposed from Cretaceous upon Paleozoic rocks; and H. B. Kummel,[2] a year later, suggested that the eastward deflection of the Connecticut at Middletown, where it leaves the yielding Triassic rocks and cuts a gorge in the crystallines, might be due to superimposition from the extended Cretaceous cover.

### THE PROBLEM PRESENTED.

The observations of A. Keith, W J McGee, and others have shown that the gently rolling upland surface of the Piedmont Plateau is a continuation of the Schooley peneplain of New Jersey and Pennsylvania. The conditions of formation of a peneplain, or even of a district well advanced in topographic maturity, carry with them the expectation of finding the streams well adjusted to the underlying structure. Since the streams of the Maryland Piedmont region are found to be unconformable to such conditions, the question arises, as to what is the cause of this discordance.

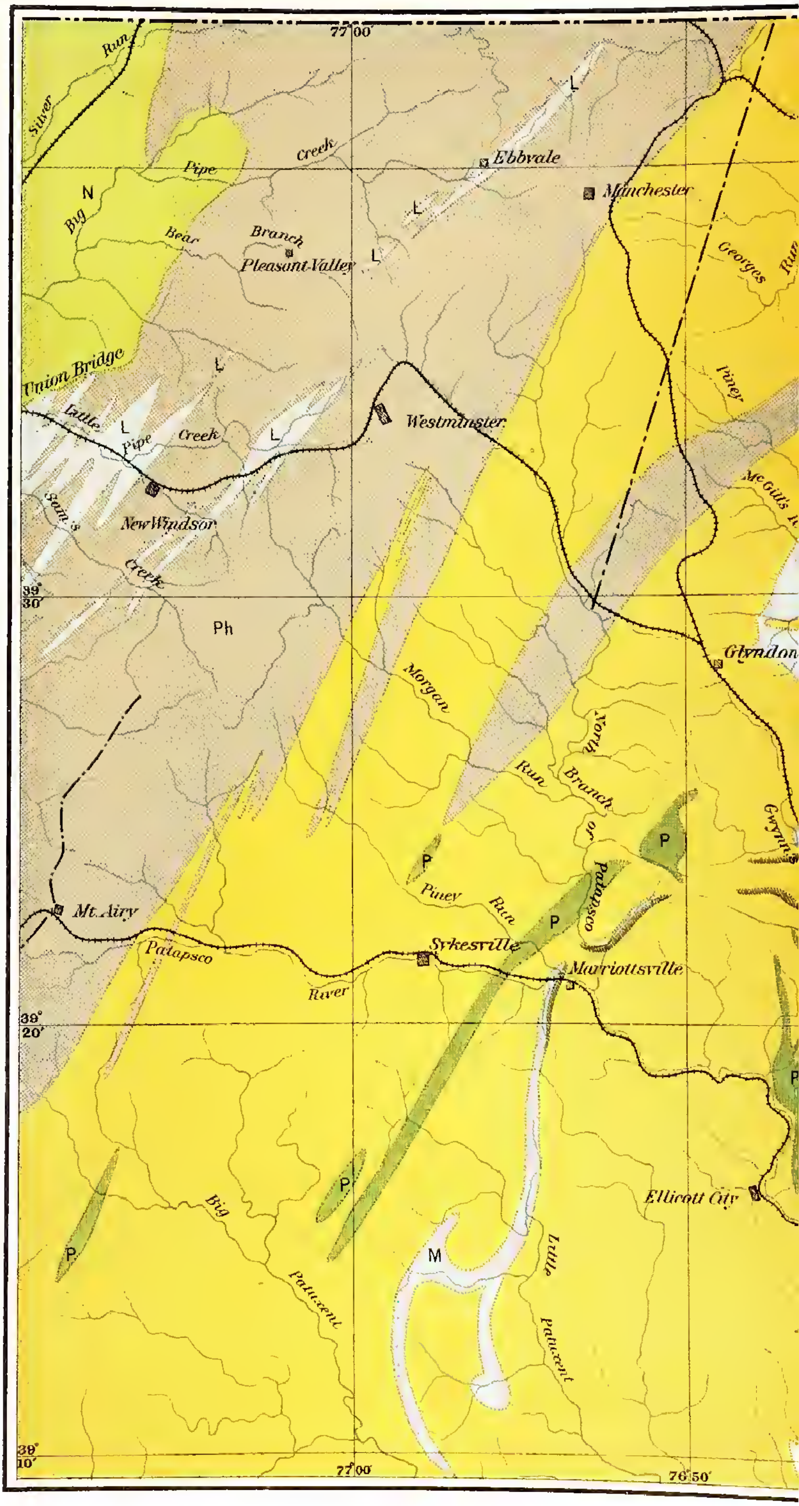
The proximity of the partially removed Coastal Plain sediments and the number of isolated patches of the Coastal Plain formations found lying beyond the general boundary of the latter province, seem to offer a ready answer to the question. This is the one suggested by McGee, viz. that the streams have inherited their present courses in large part from a previous cycle when they were located on the surface of the then more extensive Coastal Plain.

### DETAILED STUDY OF TYPICAL STREAMS.

The succeeding detailed descriptions and studies of certain streams have been made with the threefold purpose of examining the evidence

[1] Tarr, R. S., Origin of some Topographic Features of Central Texas, Amer. Jour. Sci. (3), vol. xxxix, 1890, pp. 306, etc., and Superimposition of the Drainage in Central Texas, ibid., vol. xl, pp. 359-361.

[2] Kummel, H. B., Some Rivers of Connecticut, Jour. of Geol., vol. i, 1893, pp. 371-393.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Mc Gills
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Glyndon
Morgan
Run
North
Branch
or
Patapsco
P
Gwynns
Piney
Run
Mt. Airy
Patapsco
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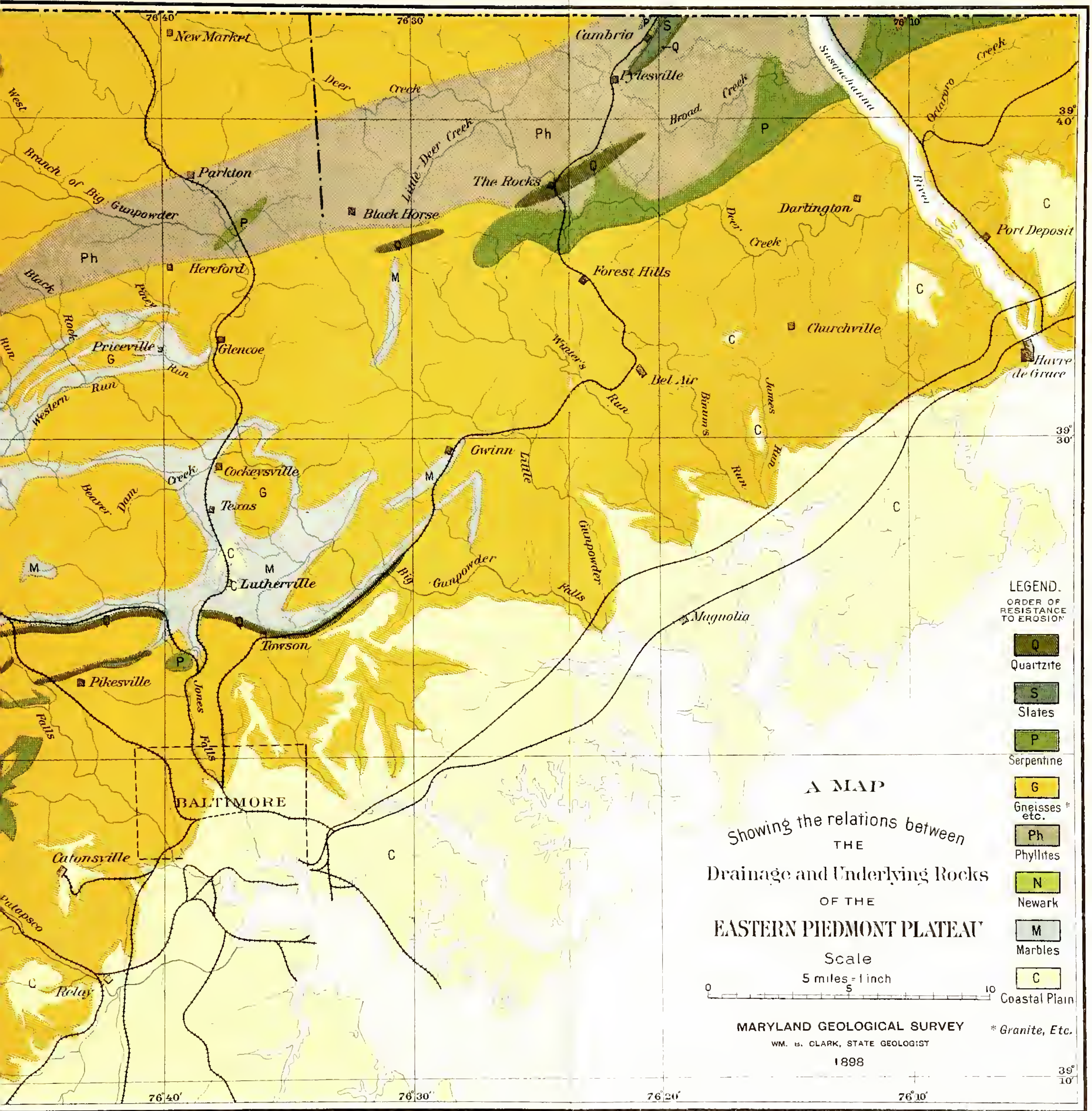



LITH BY A. HOEN & CO. BALTO

for and against the theory of superimposition; of finding, if possible, the topographic evidences which will indicate a former westward extension of the Coastal Plain blanket; and of determining the date or dates at which the streams may have been superimposed.

The systems of drainage described in the following pages are confined to the Eastern Piedmont Plateau and are represented upon Plate XVI. The area included in this plate is indicated by shading on the Index Map, fig. 15.


Fig. 15.—Index map showing location of Plate XVI.

*Deer Creek.*

Deer Creek rises in the gneissic areas of the northwestern corner of Harford county, Maryland, and southern York county, Pennsylvania, and drains the whole northwestern portion of Baltimore county. The general direction of the drainage system is southeast as far as The Rocks, where after passing through the gorge at this point the stream changes to an easterly direction and empties into the Susquehanna about eight miles above Havre de Grace. Across its path lie bands of gneiss, phyllite, slates and quartzites, pyroxenite, gabbro, and granite, each having its own characteristic topography.

From its headwaters down to The Rocks, Deer Creek and its tributaries may be regarded as a physiographic unit. This portion of its course lies partly in the gneiss and partly in the phyllite. The foliation and lines of structural weakness of these rocks strike northeast and southwest, while the general trend of the main stream is at right angles to this direction. The stream thus shows disregard for the relatively greater resistance of the silicious bands that are mingled with the much less resistant micaceous facies of the phyllites. All the stream courses are sunk below the general level of a peneplain, whose surface is well preserved in the accordant crests of many hills on either side of Rocky Ridge. The peneplain stands fifty or seventy-five feet below the long even crests of Rocky Ridge and Slate Ridge. It is particularly well developed in the vicinity of Belair, along the course of Deer Creek both above and below The Rocks and along Winter run. The appearance of the peneplain above The Rocks is shown by Plate XVII.

The hill-slopes bounding the valleys of Deer Creek and Little Deer Creek fall rapidly from the gently undulating surface of the Belair peneplain down to the broad flood-plains that characterize even the smaller streams of this system. They are frequently roughened by small ledges whose ragged faces, half-buried by the present flood-plains, show that they once bounded more rugged gorges and valleys.

Flood-plains.—The bottom-lands that characterize these streams are clearly shown by two lines of evidence to be flood-plains. Wherever fences cross the bottom-lands they are built in the form of swing gates, such as are used to fence across a stream. This indicates that floods in these valleys are frequently high enough to destroy fragile structures built across them. Again, the structure of the bottom-lands or meadows as exhibited in the banks of the streams during low water points to a constructive rather than a destructive origin. For example, a vertical section of the flood-plain on Little Deer Creek exposed but a few hundred feet above its junction with Big Deer Creek shows at the top one and one-half feet of rich black loam overlying three feet of gravel. The constituents of the gravels have a diameter of about one and one-half inches near the top and increase to boulders of a foot or more at the base. These pebbles and boulders

ROCKY RIDGE AND THE VALLEY OF DEER CREEK.

are water-worn, rounded or subangular fragments of phyllite, quartzite and vein quartz, and have evidently been derived from points near at hand. The width of the meadowland, which continues down stream as far as The Rocks, varies somewhat. It is broadest across the less resistant bands of the phyllite and narrowest in the siliceous and quartzitic areas where it reaches a minimum width of fifty feet. In spite of the fact that the valleys broaden very markedly when on the phyllites and by their narrowing indicate that the quartzites are harder to reduce, yet there is no apparent tendency on the part of the main stream to seek out a more convenient course along the more yielding rocks or to follow the strike of the foliation and jointing planes of either. This applies more particularly to Big Deer Creek, as Little Deer Creek appears to have developed its course more nearly along these lines of least resistance.

### *Broad Creek.*

The headwaters of Broad Creek, that is those west of Pylesville, have developed mild contours over their drainage basin. Standing on the refuse piles of the first slate quarry south of Cambria station one looks westward across fertile, gently rolling fields well watered by streams with broad bottom-lands, all converging towards Pylesville to form the main stream. At Pylesville it has cut its way through the slates, quartzites, and conglomerates of Slate Ridge, thus opening a passage for itself, the railroad and the highway. The creek itself is about six feet wide and as many deep at Pylesville, but after crossing the ridge of slates it opens out in a broad meadow, along one side of which it flows for five or six rods until it enters the gorge through the quartzite. This gorge has a flood-plain forty to eighty feet in width which is strewn with boulders two feet and less in diameter and is evidently submerged during moderate floods, since its present dry portions are much tangled by driftwood. The sides of the gorge rise rapidly, in the lower portion even precipitously, to a height of one hundred feet above the channel and are densely wooded. The stream flows rapidly over gravel shoals and across sharp ledges of micaceous quartzite and conglomerate at the lower end and in no part of the gorge is there even a low cascade. These facts indicate that the stream has nearly established a graded channel.

After flowing for a quarter of a mile through this narrow gorge Broad Creek emerges upon a broad meadow whose even surface stands at a level which is four or five feet above the ordinary level of the stream. This meadow-land, stretching out sometimes to a width of a quarter of a mile, runs squarely against the foot of the steep slopes of rocky cliffs descending to it from the even upland surface. The rocks underlying this meadow are chloritic phyllites that are especially subject to decay and removal wherever they are found in the Piedmont, while the more resistant bands of quartzite and conglomerate serve to retain the prominent benches and form the bare ledges which sometimes bound the meadow-land.

Viewing the topography thus far described it may be briefly summed up as follows: The primary feature of the district is the broad extent of the peneplain extending in all directions as a gently rolling surface. Running northeast and southwest and rising above the general upland are the even-crested elevations of Rocky Ridge and Slate Ridge. Besides these higher elevations there are less prominent inequalities of the surface caused by the resistant bands of the quartzitic gneiss and the serpentine which intersect the general areas of gneiss and granite. The streams pursue general eastward courses whose directions are only very slightly influenced by the variations in the rocks across which they flow. The valleys are sunk below the general upland as relatively wide trenches, except where they cross an unusually resistant band. When within two or three miles of the Susquehanna these streams lose their broad-bottomed valleys and descend to the level of the larger river through steep narrow defiles with their channels frequently broken by low cascades.

### *James' and Bynum's Runs.*

These two short streams have the same general characters and one description will serve for both. Both streams head on the mildly undulating surface of the Piedmont Plateau just south of Deer Creek. The characters of their headwaters are those of a stream on a well reduced land surface. The upper valleys are shallow and broad with very mild slopes from divide to stream channel, and the streams flow quietly through alluvial meadows with very moderate stream grades.

On either side of the turnpike from Belair to Churchville the topography is mild and is easily distinguishable from the rolling slopes descending on the north toward the channel of Deer creek. On the south the topography and character of the streams change rapidly and the broad divide merges into the more cut-up surface of the middle portion of the drainage system. The stream valleys become steeper sided and the washed-in detritus from the slopes forms small alluvial bottoms over which the streams meander during the summer. Where the streams pass the "Fall Line" they become more troubled and flow more rapidly over low cascades which alternate with short stretches of quiet water.

*Little Gunpowder Falls.*

The Little Gunpowder Falls, which forms the lower portion of the boundary between Harford and Baltimore counties, rises on the phyllites and gneisses between Monkton and Blackhorse and flows in a southeasterly course as far as the estuary of the Gunpowder river, where it enters the waters of Chesapeake Bay. In its course it traverses phyllites, marbles, gneisses, gabbros, and granites without any appreciable conformation to the differences in resistance to erosion which these various rocks present.

The headwaters show that the stream is now increasing its drainage basin, but at a lower rate than the Big Gunpowder. The rocks underlying its upper course are gneisses ranging in character from the weak muscovite gneiss to the less yielding fine-grained hornblende gneisses. Where the stream passes over bands of the latter type the valleys become somewhat contracted and the scenery a little more rugged. Lower down on its course, as near Taylorville, the Little Gunpowder crosses narrow lenses of marble which are more easily corroded than the less calcareous gneisses and schists. Wherever the stream encounters the marble it is customary to find it meandering through broad and fertile meadow-lands which are often flooded after heavy rains. The lower course of the Falls adjacent to the trestle of the Baltimore and Lehigh Railway is in a narrow gorge eighty to one hundred feet below the ordinary level of the upland. The stream channel is filled with angular fragments of gneiss, quartz and schist, and frequently has low ledges of gneiss cutting across it. The flow is rapid and the stream seems to be working steadily even when the low waters of summer enable it to handle only the coarse sand and finer gravels.

The last phase of the stream's inter-Piedmont course is entered just below the mills at Reckford, where the channel becomes of less uniform grade and is characterized by short stretches which are practically level in times of flood. The alluvial meadows built up of the sands, gravels and alluvium brought down by the floods at high water become broader and the stream flows in a more irregular course with a rapid current.

### *Big Gunpowder Falls.*

The Big Gunpowder rises on the phyllites in the northeast corner of Carroll county, and flows in a general southeasterly direction across the phyllite, gneiss and marble belts of central Baltimore county to the head of the Gunpowder estuary, where both the Big and the Little Gunpowder empty into Chesapeake Bay. The waters forming the lower courses of this river are the combined product of the confluence of three main branches forming the chief drainage lines of northern and central Baltimore county. The more northerly branches unite near Monkton and are known, respectively, as the North, or Main Gunpowder, and the West Branch of the Gunpowder. The usage of these terms is somewhat unfortunate since the more prominent and larger stream is known as the West Branch while the smaller and less important is known as the Big Gunpowder.

The North or Main Branch.—The latter rises just across the Pennsylvania line in south-central York county. As it enters the state it is relatively small, having a width of only six feet, and is only about fifteen feet wide a short distance above its junction with the West Branch near Monkton. Its valley is conformable to the size of the stream and, as far as Monkton, has a rather open character. Near the state boundary the stream flows rather rapidly through a narrow alluvial plain bounded by hills inclined at an angle of about 30° to the flood-plain. The rounded contours indicate only a moderate rate of denudation. The slopes meet the flood-plain in a sharp line and change their inclination to a much flatter angle as the crests of the hills are approached. Following down the stream the banks continue steep, but the increasing volume of water makes the lateral cutting on the outside of the curves more active, so that the banks are often precipitous on one side and relatively mild on the other. (Illustrations of these stream-cut cliffs are frequent between Bentley Springs and Monkton.) The flood-plain feature continues for some distance and the plain increases in width somewhat out of proportion to the size of the stream, with the result that the channel is now frequently on the opposite side of the valley from the vertical cliffs which the stream cut at an earlier stage of its development. The shallow, open, yet steep-sided, valley, with its alluvium-lined floor, characterizes the stream as far as its junction with the West Branch. The channel is from forty-five to fifty feet below the hilltops and from fifteen to fifty feet wide, according to the varying resistance of the gneiss. The bed of the stream is made of angular boulders with frequent ledges in the lower part of its course except where covered with sand, gravel and loam.

The side streams flowing into this portion of the Big Gunpowder Falls have their lower courses more or less flood-plained, while in their upper portions, particularly about their incipience, they are marked by steep-sided valleys that sink sharply below the general upland. Generally these streams, after flowing for a longer or shorter distance across broad, flat meadows, enter the Falls without any marked change in their grade. Such is the manner in which Owl Branch, a tributary at Turner's Crossing, and several other streams join the Falls. At Parkton, however, Fourth Mine Run is interrupted by a series of low rapids after leaving its meadow-land. These rapids are due in part to gravel-bars, and in part to ledges of the gneiss that enable Fourth Mine Run to descend about six feet in the course of the hundred yards between its flood-plain and the channel of the Falls. This seems to be an exceptional manner of junction and is probably due to the local development of a more resistant band in the gneiss at this point.

The West Branch.—The larger, more interesting, and more important branch of the Gunpowder, termed the West Branch, results from the confluence of two streams near the paper-mills southwest of Lineboro, on the Western Maryland Railroad, in the northeastern corner of Carroll county. While local opinion regards the northern branch as more important and as the head of the Gunpowder, near Melrose postoffice, there are just as good reasons for regarding the southern branch, heading north of Manchester, as of equal importance. Both of these streams flow northeast for two or three miles in narrow valleys, then unite and pursue a general southeasterly course for fifteen miles or more across the gneiss and phyllite to a point between Monkton and Whitehall, where the West Branch joins the main stream just described. In this distance it receives the waters of several large tributaries, especially Big Grave Run and Georges Run. The valleys of the two head-streams are characteristic. The northernmost, after emerging from the hills as several small rivulets, flows for some distance through a broad and open limestone valley until just before its union with the Southern Branch when it cuts directly across a band of gneiss forming a steep-sided gorge. This gorge is now filled with an artificial flood-plain, due to the construction of a mill-dam at its lower end. Since the difference in elevation between the northern and southern streams is fully twelve feet, the waters of the stream must have flowed very rapidly through the gorge before they were artificially restricted. The Southern Branch flows in steeper-sloped valleys whose cross-sections approach more closely to the shape of a V. The channels are always marked by narrow flood-plains, which vary in their width according to the character of the underlying rocks. The floor of the valley seems in many instances to be due to the solvent action of the stream and the slowly moving ground-water of the adjacent hills. The stream itself meanders over this plain in a trench, four or five feet below the surface of the valley-floor, exposing a section through alluvium, loam and stream gravels. The presence of angular blocks of gneiss, one or two feet in diameter, in the bed of the stream indicate its *efficiency* during floods.

Below the confluence of the two tributaries the waters flow through broad, level meadows, averaging seventy-five to one hundred feet in width, that make a sharp line at the base of the steeply inclined sides of the deepening gorge which widens into more gently rounded valleys where the course of the stream is over the less resistant marbles and phyllites. For example, just below Rockdale the West Branch leaves its steep, narrow gorge for half a mile or more and wanders across level meadows a quarter of a mile in width.

At the confluence of the West Branch and its tributaries the valleys usually open out somewhat, and the flood-plain extends up the valleys of its tributaries for a distance of several hundred yards. Above this flood-plain the side streams, such as Georges Run, emerge from small gorges of steep grade which they have cut through the underlying gneiss. Above these smaller gorges the streams are usually in long, broad meadows, extending back to the hills that rise to the general level of the upland.

The Big Gunpowder.—After the West Branch joins the so-called Falls of the Gunpowder the volume of the Falls is considerably increased and consequently the gorge becomes wider. The increased power resulting from increased volume is indicated by the larger rock fragments now found in its channel and also by the occasional evidences of lateral swing and corrasion found in the flood-plain. Gneiss boulders, two feet in diameter, are found in the channel of the West Branch, while in the flood-plain deposits and in the present channel of the Falls, just below Monkton, a few sub-angular fragments, two to three feet square, occur. A well-marked instance of lateral corrasion, due to increased power, is between Monkton and Pleasant Valley Station. At this point a low level-topped ridge of gneiss rises five feet above the swampy flood-plain. The ridge is almost wholly surrounded by water, even when the Falls are at a low stage, but a low neck of gneiss, about three feet above water level, joins it to the high projecting bank around whose base the Northern Central Railway passes by a cutting and an embankment.

The general characters of the gorge of the Big Gunpowder below Monkton are but slightly modified from those of the gorge above the junction with the West Branch. The flood-plain is on the whole but little wider, averaging sixty or seventy feet, and often narrows to less than fifty feet. It is always a collection of sand and fine gravel, sometimes with a foot of brown loam on its surface. It abuts sharply against the sides of the gorge, and these are either rocky cliffs or steep grass-grown slopes in which the rocky ledges are but thinly buried. These steep slopes and low cliffs rise sharply for one hundred and fifty or two hundred feet and then round off, grading somewhat less rapidly into the gentle streamward slopes of the general upland. These general features characterize the Big Gunpowder as long as its course lies within an area of gneiss or granite. The bands of marble which it crosses, however, sometimes modify the stream topography in minor details.

After receiving the waters of its largest tributary, Western Run, the Gunpowder passes through one of the most interesting portions of its course, in the vicinity of Cockeysville. While running on the marble, which extends from Ashland to Lutherville and thence eastward to Loch Raven, the stream turns sharply to the east and enters a deep, narrow gorge cut through a boss of granite, which rises three hundred and sixty feet above the level of the marble valley. The stream has scarcely any flood-plain, and at times the gorge becomes so constricted that there has not been room enough to make a road along the edge of the flood-plain without considerable blasting. The bottom-land in this portion of its course, unlike that farther up-stream, has been formed by the abrasive action of the stream on the hard underlying rocks instead of being built up by deposition. Although marble bands are encountered in the passage through this granitic area the level of the marble slopes is little below the general level of the upland surface. There is, however, a bench three hundred and fifty or four hundred feet above the course of the Gunpowder which conforms in altitude to the level of the residual portions of a pre-Potomac valley-floor that has been partially preserved in the Potomac-capped levels at Lutherville, Timonium, and points in the Green Spring Valley.

The lower portion of this gorge, which debouches at Loch Raven, has been modified by the artificial restrictions which have been constructed at the latter point, as a portion of the Baltimore water-supply system. Below the dam the stream enters the continuation of the marble belt which it left at Ashland, and continues in it until it enters the gneiss once more near Summerfield. Below this point the river flows in a gorge of increased depth and steeper sides, and the rocky channel of the river occupies a narrow trench two hundred and fifty feet below the upland, with a floor varying in width from seventy-five to one hundred feet. The narrow flood-plain extends about twenty-five feet back to the foot of the canyon walls on either side of the stream. Through it project numerous ledges, showing that there is but a thin veneer of alluvium covering the solid gneiss beneath.

The grade of the channel steepens more rapidly from the point two miles above the crossing of the Belair Turnpike to the mouth of the river, and is frequently broken by ledges and small cascades (Plate XIX). As the channel steepens the slopes of the gorge begin to retreat and to lose a little of their steepness, until after a rapid fall and several sharper cascades and rapids the river debouches into its estuary between Loreley and Bradshaw.

*Western Run.*

Western Run, which is the most important branch of the Gunpowder below Monkton, heads on the limestones and gneisses of Worthington's Valley, just north and east of Glyndon. After flowing across a small tongue of gneiss it runs eastward for about five miles, following the southern boundary between the gneiss and the marble band extending from Glyndon to Glencoe. Two miles west of Belfast P. O. the Run turns sharply southward, deserting the band of marble, and flows for four miles in a winding gorge through the gneiss until it emerges on the marble near Cockeysville, only to re-enter the granite at Ashland Furnace on its way to join the Big Gunpowder Falls, one mile above the Warren cotton-mills. The principal tributaries of this trunk stream from west to east are Gladman's Run on the south, Piney Run and Black Rock Run on the north, and Beaver Dam Creek which enters it from the southwest.

Much of the territory drained by these streams is characterized by broad, open, slightly rolling valleys of very moderate depth, bounded by rather steep slopes. The trend and boundaries of these valleys are intimately related, in most instances, to the direction and extent of the marble areas that occur as a number of narrow, approximately parallel bands, separated by narrow strips of gneiss. The drainage lines, as shown by the large scale map (Plate XVI), run directly across the general trend of the bands, and with the exception of the northern branch of Beaver Dam Creek, only small streams have courses along the marble. The general level of the area formed of these interwoven bands of marble and gneiss, is slightly below that of the surrounding rocks. The gneiss bands usually form the minor divides within the basin, but not infrequently the divides run as easily across the marble as across the gneiss. The two broader areas of marble occurring at Belfast P. O. and Mantua Mills, where the narrow bands unite, are lower than the general level of the area because of the greater solution to which they have been subjected, owing to the fact that both of them are crossed by moderate-sized runs.

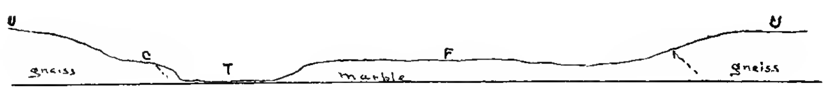



FIG. 16.—Profile across Western Run Valley.

The vicinity of Belfast P. O. and Priceville now appears as a plain, whose trenched and slightly dissected surface is indicated by the summits of gently rolling hills bounded by comparatively steep slopes of gneiss. The summits representing the former valley-floor are now covered with a thin deposit of coarse gravel and cobbles of vein quartz that have been brought from some distance and deposited by a stream larger than the Piney Run of to-day.

PINEY RUN.—Piney Run and its tributary, McGill's Run, rise on the gneiss of Baltimore county near the Carroll county line, due east of Westminster. The two streams follow parallel courses across gneiss, phyllite, and marble down to Dover, where they unite and flow by a common channel to Western Run. These streams have sharply incised and steeply bounded courses on the gneiss, with fresh flood-plains of moderate width, and channels which are largely composed of gneiss fragments and, rarely, quartz pebbles.

GLADMAN'S RUN.—Just at Mantua Mills, half a mile below the mouth of Piney Run, Gladman's Run joins Western Run. This tributary rises on the large gneiss area west of Cockeysville and flows northward across the narrow marble and gneiss belts to the main stream. The hills gather closely about its headwaters on the gneiss and rise steeply from the stream-bed, but in the marble they become lower and more rounded towards the stream, while a flood-plain thirty feet wide is developed and continues with the stream until it emerges into the flood-plain of Western Run. Small subsequent valleys are being developed on the narrow marble band, but they are clearly in very youthful stages of development. Gladman's Run, in crossing the narrow band of gneiss south of Western Run Valley, does not seem to suffer any contraction in the width of its channel. The Run is here about six feet wide and flows in a meandering course on a flood-plain fifty feet wide. Its channel is chiefly of gravels and sand. The gneiss hills are generally more or less under cultivation and slope down sharply for about thirty-five feet to the level flood-plain of the Run.

Black Rock Run.—Black Rock Run, like Piney Run, rises on the gneiss and phyllite areas northwest of the marble bands and flows southeast across the marble bands and gneiss to join Western Run near the crossing of the Falls Turnpike. In its upper course it is a small and rapid stream, three to six feet wide, flowing through a broad, level meadow-land. The flood-plain has a width of about two hundred feet on the main branch and is bounded by steep, smoothly rounded slopes of chloritic schist. A smaller tributary, flowing parallel to this portion of the main stream and lying west of it, has a very similar valley though on a smaller scale. The steep side-slopes, however, are in this latter instance less rounded and more rugged and along the lower portion of the stream course they are sometimes even precipitous.

About seven miles from its headwaters Black Rock Run crosses a narrow band of marble, at the same time turning southwest and following the southern edge of the marble for about a mile before it bends southward and again cuts into the gneiss. Just where it makes the first bend after entering its valley on the marble, a small subsequent, also located on the marble, joins the Run from the east. This small stream is bounded by steep slopes of the marble, and its head-divide on the latter is still almost as high as the general level of the gneiss-supported upland. As the junction with the larger stream is approached this narrow valley widens, the contours become milder and the general characters of a valley developed upon a marble or limestone band appear.

In this small subsequent valley, known as Stringtown Valley, better than at any other locality in the Piedmont province, is seen the influence exerted by structure on the marble valleys of the district. The foliation-planes of the gneiss and phyllite and the associated beds of marble and quartzite all have a general southeast dip with an inclination of about 30°. The planes of weakness and fracture of the marble are parallel to the planes of foliation. Therefore, a stream working out its channel on the marble would have a tendency to shift its channel laterally down the dip, because solution would be easier and more rapid on that side of the stream. This shifting would also be aided by the ease with which undermining of the opposite bank by lateral corrasion could be carried on (see Fig. 5). Now, the right or northwest valley-slope of Black Rock Run has a very mild and even descent to the flood-plain of the stream, while the left hand or southeast slope is steep and rough with the stream flowing at or near the base. The right hand slope is largely on the marble, while the left hand slope is about two-thirds on the gneiss. Thus the configuration of the valley is not symmetrical with respect to the location of the stream as is the usual case, but has a cross-section resembling ∟ with the stream at the lowest point. These unequal slopes pass down into the even levels of the flood-plain and meadow-lands through which Black Rock Run meanders for half a mile to its confluence with the smaller western branch.

At the junction of the two streams the course turns southward into the gneiss and enters a wild, narrow gorge just above Butler P. O. This gorge is half a mile long, scarcely two hundred feet wide, and its steep, rugged slopes are often bare, rocky ledges which stand out as ribs of gneiss or quartzite. The cliffs slope abruptly down two hundred feet to the rocky channel of the stream. About a quarter of a mile from the head of the gorge there is a band of resistant quartzite which has withstood the wearing of the stream so well that a waterfall thirty feet in height still bears witness to the hardness of the ledge, although the channel has now cut down one hundred or one hundred and fifty feet below the top of the gorge. This ledge has been utilized as the foundation of a mill-dam which still ponds the stream above the falls, though the mill which it once supplied with water-power has now fallen to pieces. Above the falls the stream is quiet and inactive, but below the dam there is a rapid current in a channel of steeper grade. It should be observed that the level, down to which Black Rock Run has and can reduce the upper portions of its channel and valley, is determined by the depth to which it can cut this resistant quartzite band in the gneiss. In other words, the level flood-plains and the floor of Stringtown Valley are incipient local peneplains controlled by the quartzite sill. The lower portion of the channel is filled with large and small fragments of quartzitic rocks which bear witness to the great transporting power of the stream at high water. Leaving this narrow course on the broader band of gneiss, the Run occupies a steep-sided but more open course on the narrow marble band just above Butler P. O. There the stream begins to develop a small flood-plain which continues across the gneiss at Butler and widens perceptibly where it joins the meadows along Western Run.

Beaver Dam Creek.—The headwaters of Beaver Dam Creek have their beginning about in the centre of the large gneissic area lying west of the Cockeysville marble quarries and north of the Green Spring Valley. The stream occupies a rather shallow, open valley on the gneiss uplands and descends through a steep, narrow, wooded ravine with very steep grades to emerge from this shut-in portion of its course near the marble quarries at Cockeysville. Thence it follows a northeasterly course across a broad rolling valley of marble, two miles in width, until at Ashland a sudden turn to the east carries the Creek against the gneiss hills overlooking Cockeysville on the east. Through these high hills it has cut a gorge a mile in length, three hundred feet deep and fifty feet in width in its course to the Gunpowder.

A large branch of Beaver Dam Creek drains the eastern half of a narrow marble band and valley lying north of the gneiss on which Beaver Dam Creek heads, and joins the Creek on the north, midway between Cockeysville and the quarries. Thus its whole course lies on the marble. The headwaters of this branch have worked back westward along the marble about as far as the headwaters of Beaver Dam Creek, but the side branching of the latter stream is much more intricate than that of the former. Small side-streams of this northern branch have cut relatively short steep-sided ravines in the gneiss slope on either side the marble, but they are very limited in their extent and are as yet mere tendrils reaching out only a short distance from the main stem. This branch of Beaver Dam Creek (incorrectly designated as Western Run on the Baltimore sheet of the U. S. Geological Survey) has its narrow valley partially filled with iron-ore bearing sands and clays, which are similar to and evidently of the same age as those found in the Green Spring Valley and in the vicinity of Lutherville. These deposits are mainly confined to the southern flank of the valley and extend half way up to the top of the gneiss hills. Besides these terrace-like deposits about Oregon the smooth floor and gentle, even slopes of this valley are sparsely strewn with gravel and small cobbles of not more than five inches diameter. The valley thus simulates in every way, except in size, the even-floored, gravel-strewn Green Spring Valley, and the same kind of evidence points to its having had the same origin and history.

*Jones' Falls.*

Jones' Falls, like Western Run, drains a valley located along a marble band, the Green Spring Valley, and so far appears to have taken advantage of the opportunities offered by calcareous rocks for developing a drainage basin with the smallest possible expenditure of energy. It also takes an anomalous course across a point of comparatively unyielding gneiss when it might have followed an easier course around the point, by keeping to the marble. These two contradictory performances by the stream, as well as the considerable amount of interest that many of the inhabitants of Baltimore are forced to take in the stream, are sufficient to draw attention to it.

Jones' Falls may be said to originate on the gneiss northwest of the small oval marble area called "The Caves." Three quite minutely branching streamlets flow from the gneiss into the basin-like depression of "The Caves," and there uniting in one stream, pass out through a deep, rugged defile leading from its southeastern corner. The stream continues in a steeply bounded course until it reaches the Green Spring Valley, west of Chattolanee and opposite the station of Stevenson on the Green Spring Valley branch of the Northern Central Railway. Here it is joined by the somewhat smaller stream that has pushed its head along the Green Spring marble out to Reisterstown Turnpike. The principal fork of this small tributary heads on the gneiss northeast of Chattolanee Hotel and flows south, while a small run flowing north from the same point drains the southwest corner of "The Caves." The crest of the divide between these two small runs is relatively wide and below the general elevation of neighboring stream-divides. The crest of this low, saddle-shaped divide stands at five hundred and forty feet above the level of the sea, while the altitude of divides between much larger streams in the immediate neighborhood averages at least six hundred feet, and the general altitude of the rolling upland plateau is six hundred and fifty feet.

It is a noteworthy fact that all the streams joining Jones' Falls from the south are small and insignificant in volume, though two branches of good size unite with the main stream on the west of Rockland and the large West Branch at Mt. Washington brings a considerable volume of water to swell the stream. This characteristic of shortened affluents from the south may also be observed in the case of Mine Bank Run and its fellow of the Gunpowder drainage west of Loch Raven station, and to an equally marked degree in the case of Western Run. Such unsymmetrical drainage patterns, departing so widely from the normal plan, which is beautifully exhibited over neighboring portions of the Piedmont Plateau, indicates that some disturbing factor is, or has been, acting to cause these variations. It is true that along the south side of the Green Spring and Mine Bank Run valleys there is developed a heavy quartzitic phase of the general gneisses which is lacking on the north boundary, and it is natural at first to conclude that the stunted growth of the streams entering from the south is the result of the superior resistance offered by this quartzite band. This is undoubtedly an important factor and it must be conceded that, in part at least, the slight development of these streams may thus be accounted for. When, however, the two sets of tributaries which supply Western Run are compared in a similar way it appears that here also there exists a greater development of the northern tributaries. The lithologic conditions in the two cases are often precisely the reverse. No resistant band of quartzite runs along the southern boundary of the main valley. On the contrary, the quartzite, which is frequently associated with the Piedmont marble bands, has been found chiefly, if not solely developed along the northern boundaries of Western Run Valley. Indeed, it is a significant fact that in the cases of Black Rock Run and others, the streams have cut gorges through beds of quartzites and yet exhibit a greater headwater development than the smaller tributaries of Jones' Falls.

These facts make it impossible to explain the development of the streams by regarding them as merely the products of the usual shifting of divides controlled by the lithological variations in the territory drained.

Two explanations for this unsymmetrical development of tributaries may be offered. The first is that a general tilting of the land toward the south has increased the activity of the southward-flowing streams, while it has put the northward-flowing streams at a disadvantage. The second explanation assumes that originally the general trend of the whole drainage was continuously southeastward, but that certain streams, favored by being originally located on the less resistant marble, have subsequently developed rapidly along these lines of least resistance, have intercepted and diverted the southeastward drainage lines and, deepening their valleys, have developed short, young side-streams from the south while keeping the long, old tributaries from the north.

Proceeding according to the first hypothesis, suppose that Fig. 17

represents the cross-section or cross-profile of a valley and its side slopes, drawn to natural scale. The main stream at ordinary stage wanders somewhat from side to side of its valley *V* building a narrow flood-plain. It is supplied by side-streams which drain the general surface of the upland *R* — *P*, and may be assumed to be equally developed on either side. As long as the land remains in this attitude erosion and stream development will proceed evenly and no peculiar features will be developed which cannot be referred to the usual processes of stream evolution upon a terrane of varying lithologic character. There will be a rapid development by the streams of a grade that will represent a balance between the volume, the load and the declivity of grade of the stream. The grade thus established will be maintained as long as the factors which have determined it remain constant. If from any cause this condition of affairs is altered by a tilting to the left the balance of forces before obtaining


FIG. 17.

will be disturbed and changes in stream activities must result. The immediate effect of such a tilt is to alter the slopes of the beds of those streams whose directions were more or less at right angles to the axis of tilting. A little study of the figure will make it plain that such a change in the general attitude of the land will decrease the steepness of the slope from *R* to *V*, while the valley-slope from *P* to *V* will have increased declivity. Moreover, since the valley-bottom *V* has an appreciable breadth it also will undergo tilting towards *R*, and the effect will be a shifting of the stream towards the latter point. The streams whose courses lie from *P* to *V*, having their beds steepened, would experience an increase in the velocity of their currents, a corresponding increase in cutting power, and a consequently increased rate in the deepening of the channels and in the extension of the headwaters. On the other hand, the streams flowing from *R* to *V* would experience a decrease in their slope and a consequent loss in their velocity and cutting power.

They would accordingly not be able to extend their drainage areas as rapidly as before, or to deepen their channels. If sufficient time elapses it must come to pass that streams on the slope $P — V$ will extend their headwaters at the expense of streams on the slope $R — V$, thus shortening the latter streams.

In an area which has been tilted, therefore, the streams flowing in the direction of the tilting will have deeper valleys, more rapid currents, and an increased branching among their headwaters. The streams flowing against the tilt, on the other hand, may be of the same depth as before the tilting, or possibly even less, since the decreased velocity of the streams may cause them to deposit some of their load of debris. They may not extend their drainage basins by headwater erosion and may even suffer some shrinkage in volume as the result of the encroachment of the other more favored streams.

A comparison of the conditions demanded by the preceding explanation with those obtaining in the main streams and tributaries of Jones' Falls and Western Run shows that while there are many points in common the degree of coincidence is not marked. Although the streams flowing southward uniformly have greater development and are more aggressive and powerful than those flowing northward, and although the streams flowing eastward follow the south side of their valleys more or less closely, yet those flowing northward are rarely one-half as long or one-third as well supplied with smaller side-streams as those from the north. The former, moreover, do not show any sign of decreasing in volume or lessening of grade, but, on the contrary, present the steeply bounded, narrow valleys with high-grade channels that characterize side-streams in their earlier stages of development. It is, therefore, evident that the preceding hypothesis of a general tilting does not fully explain the unsymmetrical distribution of the tributaries.

The second hypothesis, based upon a partial rearrangement of the drainage lines of the two streams from a former, more southerly course, requires at the outset some competent means of placing the large and small streams in their initial positions across the marble and quartzite beds. This may be accomplished by supposing the whole network of drainage lines newly located upon the face of the country across gneiss, quartzite, marble, or serpentine without reference to any differences in resistance.

Starting with an initial arrangement of the drainage somewhat as shown by the accompanying diagram, Fig. 18, the history of the stream may be inferred as follows: As the various streams cut their channels deeper and gradually pushed out their headwater and side-streams, the branches already located on the marble and the new tributaries there originating were able to grow in size and power more rapidly than the streams located on the resistant gneiss and

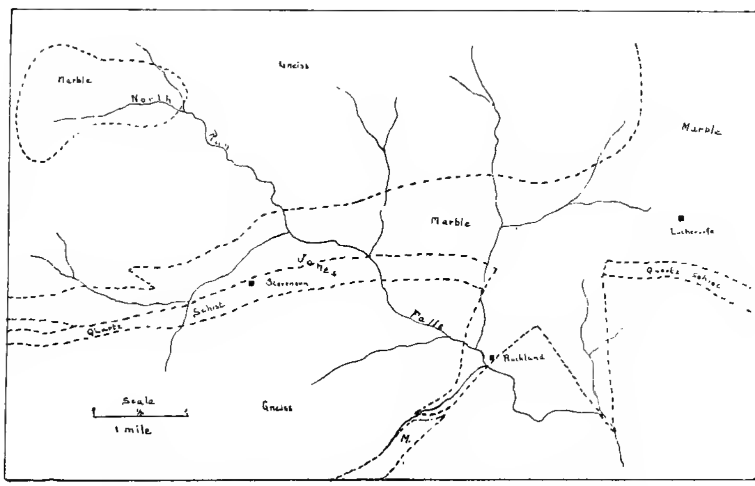



FIG. 18.—Former unadjusted course of Jones' Falls.

quartzite. These favorably located streams thus outstripping in their growth the others and guided in their development by the course of the marble bands would soon cause some readjustment of the smaller streams. For example, a small side-stream beginning near Rockland may have worked northward past the quartzite ridge and acquired headwaters from the north and side-streams on the marble.[1] Starting

[1] This is a very probable change, for a stream flowing across the point of gneiss with its hard, resistant quartzite facing, would need a very long time to reduce its channel, while a much smaller stream starting on the soluble marble would wear down its course very rapidly.

from the same point, Rockland, the smaller stream would then reduce its channel to a lower grade than the slightly larger stream on the gneiss could possibly do in the same time. Soon a critical stage in the position of the divide between the two streams would be reached. The smaller stream, from its lower grade, could push its divide nearer and nearer to the main channel of the larger and higher stream, until at last the latter would be intersected and all the waters of its upper course be diverted into the channel of the small invading

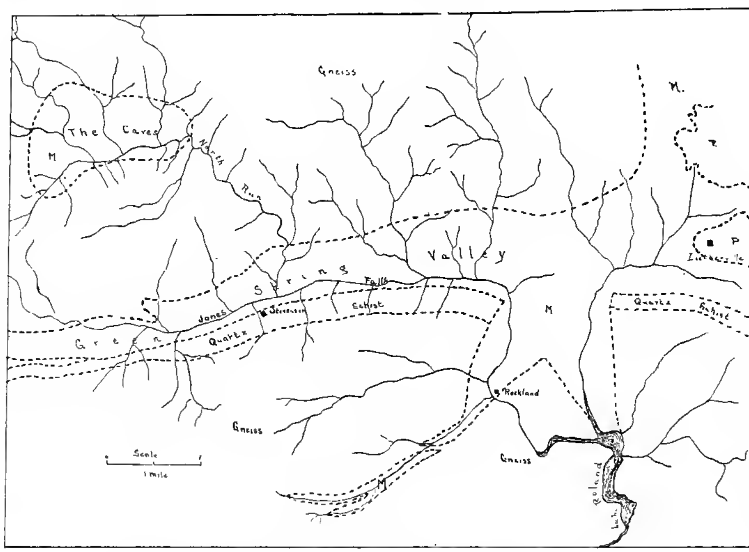



FIG. 19.—Present partially adjusted course of Jones' Falls.

diverter. The lower course of the beheaded stream would continue in its former channel but much shrunken in volume and unable to push its headwaters against the opposition of the more powerful and favored pirate stream that cut off its headwaters. The same or closely similar changes would be going on between the other streams where they cross the marble belt. Various interstream adjustments probably would occur until, finally, Jones' Falls, as at present, favored by the long stretch of marble down to Lake Roland and Rockland, had captured the heads of all the streams crossing the eastern portion of the marble, and led out the drainage by one common channel around the gneiss and down to Rockland.

While these changes in the stream courses were slowly being accomplished the streams must have been gradually deepening their channels in the gneiss until one by one they were diverted to courses on the marble. If this is the manner in which the Jones' Falls and Western Run systems were developed, there should be some traces of the valleys carved by the streams before their diversion. Since no such abandoned channels have been found, it must be inferred either that the diversion of the earlier stream courses proceeded so rapidly that the courses on the gneiss were not deepened sufficiently to permit of their being distinguished amidst the various inequalities now existing, or that the early streams were not originally placed as supposed but were gathered into common channels along Green Spring Valley and Western Run.

A third hypothesis assumes that the sediments of the Coastal Plain were formerly thick enough in this area to completely mask the former Piedmont topography, and that the streams were located independently of earlier valleys and divides and were controlled only by the surface configurations of the Coastal Plain.

No one of these various hypotheses is entirely satisfactory and the facts at hand seem to indicate that this unsymmetrical distribution of the tributaries is not due to a simple cause but is the result of the combined action of two or more such sets of conditions as have been implied in the foregoing hypotheses.

Age of Jones' Falls.—At several points along the lower course of Jones' Falls, especially within the corporate limits of Baltimore city, are beds of coarse gravel, sands, and clays, resting on the beveled edges of the gabbro and gneiss. The line of contact between these two formations is well shown near the eastern end of North avenue bridge and at the Jones' Falls gneiss quarries some distance up-stream. At both exposures the contact appears as a sharply drawn horizontal line separating the even, flat surface of the eroded crystallines from the heavy deposits of gravel which have been determined by Darton [1] as of

[1] See "Geological Map of Baltimore and Vicinity," Geo. H. Williams, Ed.; pub. by Johns Hopkins University, 1892. N. H. Darton on Sedimentary Formations.

Pleistocene age. Similar gravels are found scattered over the limestone floor of the Green Spring Valley. At a point opposite Stevenson fifty or sixty feet above the present stream channel are located some old abandoned iron mines. The exposures in the open pit show the following section of sedimentary deposit. At the bottom are about fifteen feet of stratified mottled red and white clays with several beds of fine, white quartz sand and clayey pellets. Above the sand and clay pellet bed come two or three feet of gravel in which the diameter of the pebbles does not average above three or four inches. The pebbles are of quartz and well rounded, and may therefore be set down either as of marine littoral or of fluviatile origin. These characteristics ally the deposits with those of the Potomac[1] group, and this correlation is corroborated by the fact that neighboring portions of this same marble tract are overlaid by Potomac beds. It is therefore evident that the depression now called Green Spring Valley and occupied by the headwaters of Jones' Falls was in existence as a depression in Potomac time, and that it was submerged during the same period and received the deposits above mentioned. Later, the Pleistocene gravels were spread over the eroded surface of these earlier formations and through these clays, gravels and crystallines the present Falls has cut and is still cutting its lower gorge. The stream at this point must, therefore, be younger than the Pleistocene deposits below which it has trenched its channel.

Discussion of Profile.—The accompanying line drawing, Plate XIX, represents in some detail the varying slope or grade of Jones' Falls channel, and a study of this profile brings out several interesting facts concerning the development of the stream. The first obvious fact is that the bed of the stream, where located on rocks, approximately uniform in lithologic character, has well-defined and widely recognized features. Starting from the divide the grade is at first very steep but rapidly loses its declivity, and for two-thirds of its length approaches the horizontal by constantly decreasing amounts. The normal grade is shown by the dotted line below the solid one representing the profile of Jones' Falls. While the upper half of the Jones' Falls curve is substantially in accord with the normal profile,

[1] Report of Maryland Geological Survey, vol. i, 1897, p. 190.

the lower half of its course deviates very markedly from the latter curve. Instead of being slightly concave and very nearly horizontal the channel descends by a decidedly convex curve. Thus the upper half of the stream is characterized by a matured and perfected grade profile, while its lower course has a very youthful character.

Besides this marked change in the general form of the stream's grade between Green Spring Valley and Baltimore, there are several smaller cases of sudden change of grade extending over shorter stretches. The best-defined localities, where these breaks in the even continuity of the grade occur, as shown by the drawing, are at and just below the dam at Lake Roland, at Woodberry and Hampden, opposite Druid Hill Park, and in Baltimore between Eager and Preston streets. At each of these points the stream drops from ten to twenty feet by low falls or cascades within stretches of fifty yards or less. An exception is found at Woodberry where, in the course of half a mile, the stream falls forty feet. These several interruptions in the evenly descending profile of the stream might be due to one of two causes, both of which are to be found within the Piedmont Plateau province. A band of rock more resistant than adjacent rocks down-stream will produce such falls, because it will persist as more or less of an obstruction to the stream after the more easily removed bands down-stream have been worn down to a lower level and a milder slope. Falls due to such obstructions are especially common in the Appalachian region where the mountains and ridges are composed of strata of different degrees of resistance. A more closely allied illustration is found at the rocks of Deer Creek where quartzite and conglomerate produce a cascade in Deer Creek because they are more resistant than the foliated micaceous gneiss farther down-stream.

The second cause for such cascades is dislocation. If a plane of dislocation or faulting with the up-throw on the up-stream side, or the down-throw on the down-stream side, cross the channel of a stream, then, supposing any considerable dislocation to have taken place along that plane since the stream began to cut its channel, it is plain that there must be some cascade or fall in the stream from the uplifted side to the down-thrown side of the plane. McGee[1] has explained the cascades on the eastward-flowing Piedmont streams by assuming both causes. In the particular case of Jones' Falls, and also on one or two other streams, it is found that most of the cascades and falls occur where dikes of medium-grained pegmatite have been intruded in the gneiss. This pegmatite is less easily corraded than the foliated, micaceous gneiss, and therefore stands out in slight relief on the steam-bed as the sill of the falls. There are no evidences of special faulting in the immediate vicinity of the cascades except in the drop just below Lake Roland; but as there are undoubtedly numerous small faults throughout the Piedmont, it is possible, perhaps probable, that these fall-points are located by such dislocations as well as by the more resistant pegmatite.

The recent elevation of the stream basin, inferred from the trenching of the Jones' Falls channel below the Pleistocene gravels, is verified by the character of the stream's profile. The concave profile of the up-stream area contrasted with the convex profile lower down clearly indicates that, after once having reduced its channel to a normal profile (Fig. 3) and having had the Pleistocene gravels and clays spread along it, a subsequent uplift has incited the stream to renewed activity in cutting its channel to the new and lower base-level. When a stream thus begins to reduce its channel to a new level the start is made at the lowest point, or the mouth of the stream, and thence the work of reduction proceeds backwards up-stream. The profile suggests that the Falls is already approaching its new grade along that portion of its course between North avenue and the harbor, but the convexity of the profile between Baltimore and Lake Roland indicates that along that portion of its course the down-cutting of the stream is still insufficient to counteract the upward tendency of the land. The profile of the Falls in Pleistocene times, as evidenced by the levels of the remaining gravels, is represented by the dot and dash line of the drawing.

[1] W J McGee, U. S. Geol. Surv. 8th Ann. Rept., 1885-6, p. 620, etc., and plate lxviii.

*Patapsco River.*

The drainage basin of the Patapsco may be divided into two subdivisions of unequal size and power, corresponding to the two main branches of the river. The larger stream, or the North Branch, which has its headwaters on the eastern slope of Parr's Ridge in the vicinity of Westminster, flows southeastward about ten miles to the Baltimore county line, near Glen Falls, and then turns southward following a somewhat tortuous course to its junction with the South Branch between Marriottsville and Woodstock. The smaller, South Branch, also rises on Parr's Ridge, about sixteen miles south of Westminster, in the immediate vicinity of Mount Airy, and pursues a winding course whose general direction is due east for about sixteen miles before it unites with the North Branch to form the main stem of the Patapsco. From this confluence the Patapsco pursues a broadly curving course, turning finally southeastward and eastward to enter the head of the Patapsco estuary, twenty miles from Marriottsville.

South Branch.—The South Branch occupies a shallow, meandering gorge depressed about two hundred feet below the general level of the Piedmont upland. The valley of the stream in its upper portion has few canyon-like characters, but is comparatively broad and shallow on account of the somewhat less resistant nature of the rocks in this district. Small lenses or bands of rock of greater resistance cross the valley, for example, at Woodbine Station or on the railroad between Hood's Mills and Morgan, causing the bounding slopes to increase in declivity and the valley to become slightly narrower. A short distance above Sykesville the valley begins to lose the more open character of its upper portion and gradually narrows and steepens, its side-slopes assuming the more gorge-like characters which it retains with minor variations down to its junction with the North Branch.

The particular bands of resistant gneiss mentioned above have special interest because of the marked influence which they have exerted on *the development of the flood-plains* of the stream and on the past industries of the locality. By reason of the resistance which these bands offer to the down-cutting of the channel, small side-streams flowing into the South Branch above them have, with the aid of the larger stream, developed marked expansions of the valley and the flood-plain. The resistant ledges produce low falls in the main channel and have furnished favorable sites for two mill-dams. The quiet waters of the ponds produced by these dams were favorable to the deposition of considerable quantities of mud which have partly obscured the surface of the eroded expansions of the valley. Now that the dams are broken the ponds are drained and their old bottoms have become green swamp- and bog-lands, resembling the poorly drained surface of a glaciated district, or the former channel of a beheaded stream.

The flood-plain, which is so extensive in the upper portion of the stream, gradually contracts down-stream until it reaches the more confined gorge portion, where it attains a fairly uniform width of two hundred feet. The channel itself is often located on ledges of the metamorphic rocks only thinly covered by beds of gravel and sand, and is sometimes broken in its descent by bare ledges of the rocks appearing through the flood-plain deposits.

All of the more important side-streams of the South Branch, such as Gillis Falls, Piney Run, Piney Branch, and Winter Run, are situated on the northern side of the main stream. As they differ in many respects from the larger stream they deserve especial mention. Their courses may be divided into three portions. The lower parts of the streams are generally occupied for two hundred yards or more by extensions of the flood-plain which bounds the channel of the main stream. For this distance the small valleys are more open than they are higher up-stream and the side-slopes are no steeper than those facing the South Branch itself. In the second portion of their courses the broad flood-plains become more constricted, the steepness of the side-slopes increases, and the stream channel becomes rocky or filled by boulders whose size often indicates that they have rolled from the neighboring slopes, since they are too large to be moved even at flood stage by the stream whose channel they obstruct. Above this zone of rapids the streams are again characterized by flat, alluvial plains, bounded by steep, rounded hills, which rise sharply from the surface of the latter to heights of one hundred or one hundred and fifty feet above the meandering channels.

The bottom-lands themselves are composed mainly of black loam with sand, gravel, and irregular fragments. They are well exposed in sections made by the shallow gravel-floored trenches, from one to three feet deep, which the meandering streams have incised in them. These valley floors in the upper courses of the side-streams are due to washing-down from the hills of such quantities of soil and rock debris that the small streams fed by perennial springs in these valleys are unable to keep their courses free.

The South Branch and its tributaries as a whole do not exhibit any striking *degree of adjustment* to the general structural features of the area of that portion of the Piedmont Plateau which they drain. The foliation and various lithologic bands have a general northeast and southwest strike, across which all the streams except the smaller tributaries flow indifferently eastward and southeastward. Definite examples of minor adjustment are not recognized except in the case of a small stream entering from the south at Marriottsville, but the most probable cases are all located on the south side of the Branch. These streams are all of small size, the longest being hardly more than five miles in length, and have their lower courses in general accord with the strike of the foliation of the rocks.

At Marriottsville a small stream about three miles long has developed along the narrow band of marble which extends south from the town for about ten miles. The stream follows the marble closely and has developed a level-floored valley much like the smaller tributaries described below. Although a subsequent stream, it has not as yet captured all the territory covered by this belt of yielding marble, nor are the remaining six miles or so to the south occupied by subsequent streams, as might be expected. Small branches of the Little Patuxent headwaters cross it in obviously fortuitous paths and a branch from the Middle Patuxent, somewhat larger than the stream at Marriottsville, also sends out branches which cross and recross the lithologic boundaries without regard to the character of the rocks.

A striking instance of non-adjustment is found in the case of Winter Run, which rises in the area between the South and North Branches and pursues a general east-southeast direction to Marriottsville, where it joins the South Branch. The upper two-thirds of the valley are broadly open, rather shallow, and characterized by a flood-plain of moderate width which is sometimes rather boggy. The course of the stream and of its small tributaries is everywhere at variance with the general strike and structure of the gneiss. This discordance becomes more marked where the stream is observed to have chosen and persisted in what proved to be a difficult path across a broad band of steatitic serpentine, through which it has had to cut a narrow gorge. If the stream had been free to choose it could have found much easier paths on either side of the band.

The difficulty with which the Winter Run gorge is being cut down shows very clearly that the extensive headwaters of the Run were not developed after the stream had cut its way back across the gneiss and the serpentine, for had such a process been necessary some stream starting on the marble would have developed faster and would now be the main stream instead of the present Run.

North Branch.—The North Branch of the Patapsco, which rises in the vicinity of Westminster, occupies in its upper course a relatively broad, shallow valley, bounded by steeply sloping, rounded hills that rise one hundred feet above the small run at the river's source. Opposite the source is a low sag in the usually even crest of Parr's Ridge, which forms the divide.

The North Branch is characterized throughout by a *flood-plain* of very moderate width, whose general characters vary but little from one portion to another. For several miles down-stream from the source, and to a considerable extent along the headwaters themselves, there is a relatively broad plain of decidedly marshy character that has not been developed as the result of retarded down-cutting in the channel as was the case on the headwaters of the South Branch. This is more probably due to the dams which have been built both at Tannery Station and higher up at Westminster.

As the valley begins to expand, forming the broader reach between

Patapsco and Glen Falls, the flood-plain widens into rich, fertile meadows two or three feet above the level of the winding stream at the usual stage of the water. Where the gorge makes a decided curve the meadows become broadly developed on the convex side and sometimes a terrace ten to fifteen feet above the flood-plain is preserved there also. The broad, flat meadows accompany the North Branch as far as Glen Falls Station where, at the confluence with Glen Falls and a small stream from the north, they unite with the flood-plains of the latter streams and form a broad, triangular plot of moist meadow-land.

Before passing on to a consideration of the lower course of the North Branch mention may be made of the sets of *river terraces* which have been developed along the portion of the stream just described. Two well-marked terrace levels stand above the broad meadow-lands and occasionally three may be distinguished. The lowest terrace, which is not always found, stands four or five feet above the meadows and is most often seen where the stream has cut an ox-bow channel behind a higher portion of the meadow-land, leaving an isolated remnant of a former flood-plain, which is not now submerged even during the heaviest floods. Examples of this terrace, which is largely composed of loam and fine gravel mixed with sand, may be seen along the Western Maryland Railroad between Finksburg and Patapsco Station.

The second terrace stands about ten feet above the meadows and five or six feet above the first one, and is built of coarser quartz gravel, sand and loam. This terrace is from thirty to fifty feet in width, and a very persistent feature as far as Glen Falls where it merges with certain terrace gravels belonging to the Glen Falls terrace.

On the steep hillside eighty or ninety feet above the stream channel is the third terrace represented by limited areas of water-worn gravels and rounded or sub-angular pebbles. The quartz, gneiss, and quartzitic rocks which contributed the materials of these thinly spread deposits, as well as the materials of the lower terraces, occur in the immediate vicinity. As there are no traces of water-worn deposits upon neighboring hilltops it is probable that the gravels of this highest level were supplied from fragments obtained in the immediate vicinity of the stream. The absence of any traces, upon the hilltops, of the Lafayette does not, however, prove that these gravels do not represent the worked-over remnants of such a deposit. On the contrary it is quite possible that they are the only remaining evidence of the former presence of that formation in this district.

Below Glen Falls the terraces decrease in importance, usually being absent or developed only where some broad swing in the course of the stream has left the old flood-plain on the convex side of the curve. As a rule, only a single terrace is found, corresponding in elevation to the second one in the series of the upper portion of the stream. At the mouth of Beaver Run, two miles south of Finksburg, the broad flood-plain of the Run joins the relatively narrower one along the North Branch and lies about twenty feet below a broad, flat, sandy terrace, forming the point between the Run and the North Branch. Again, two miles north of North Branch Postoffice a mill has been built on a flat terrace, twenty feet above the channel, which passes around it in a broad swing. The section which the stream makes where it cuts through the terrace shows that the latter is composed of water-worn cobbles, gravel and pebbles, generally iron-stained and overlaid by two feet of angular fragments of the black hornblendic schist which forms the neighboring hills. The last locality where the terrace gravels were seen before reaching the confluence with the South Branch was half way between the latter point and North Branch Postoffice. At this place a stream of moderate size, which rises on the land between Hernwood and Harrisonville, empties into the North Branch just east of a low knoll of marble. On the crest of this marble knoll and extending down its slopes for ten or fifteen feet is a thin veneer of gravels and pebbles closely resembling in lithologic characters the materials of the second terrace found along the upper course of the North Branch. At the southern foot of the knoll the North Branch makes a smooth swing to the northeast and east in a muddy and sandy flood-plain, which the small side-stream has helped to build.

The *small tributary streams* which combine as the headwaters of the North Branch and others near Patapsco Station flow at the bottom of relatively deep ravines. Their channels are usually somewhat winding as they occupy narrow flood-plains strewn with angular fragments which have rolled from the surrounding slopes. Sometimes a stream crosses a band of quartzite or a quartz vein and then the little valley grows narrower and the channel steeper. Generally the headwaters of these small side-streams are characterized by open, shallow catchment basins which form but slight depressions and belong to the rolling surface of the Piedmont upland. Those larger streams which join the North Branch along its lower course generally correspond more closely to the types illustrated by Glen Falls and Winter Run, while the sides of the gorge, particularly along its lower course, are serrated by small brooks of uniformly steep grade confined between high, steep banks. These latter streams do not take their rise any considerable distance back upon the plateau.

Glen Falls, which is a stream about four miles in length, heads in the vicinity of Glen Morris and Emory Grove. It begins as a small rapid rivulet, flowing in a narrow wooded ravine, but within a mile it is joined by several side-streams which swell its volume to a run of some size. Simultaneously with this increase in volume of the stream the valley widens and the flood-plain develops, gradually increasing in width until it merges into the broad meadows at the confluence with the North Branch. The side slopes of the stream are steep and rounded, and descend sharply to the surface of the flood-plain.

One of the interesting tributaries of the North Branch is the small stream already referred to as rising between Hernwood and Harrisonville and joining the North Branch between North Branch Postoffice and the confluence. This stream, though having its headwaters situated on the gneiss of the Piedmont, follows throughout most of its length a subsequent course located on an S-shaped band of marble. This marble band appears to be a detached portion of the long strip of marble which stretches southward from Marriottsville and, like the latter, has a band of quartzite along its eastern edge. On the marble the stream has developed, by the solvent action of its own waters and the ground-waters which gradually drain into it, a wide, level-floored valley of rich alluvial soil. Below this meadow-land the Run has sunk its channel from two to ten feet, the amount increasing down-stream. At the highest floods it does not appear that the meadow-land is extensively submerged, although the trench is evidently filled. Twenty or thirty feet above the meadows a narrow level bench runs along the valley-slopes, coinciding approximately with the line between the marble and the gneiss. This bench is somewhat better marked on the northwest side of the valley. On the southwest side the band of quartzite causes the whole southwestern slope to rise more steeply than does the opposite one.

At the mouth of the stream a marble knoll, rising thirty-five feet above the channel, embraces nearly all of the area occupied by the marble. On the west of this eminence is a small side-stream, while on the east the main stream cuts its course across a resistant band of

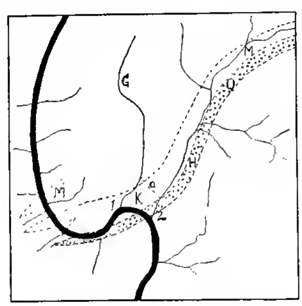



FIG. 20.—A minor adjustment in a side stream of the North Branch of the Patapsco.

quartzite and the gneiss beyond, which lie on the eastern border of the marble. Behind the knoll between these two valleys is a low saddle which is not covered with stream gravels. Through it now passes the road from Hernwood to Marriottsville. An explanation for the relations existing between the gravels capping the marble hill, the location of the run on the quartzite, and the saddle in the marble behind the knoll, is shown in Fig. 20.

The low marble knoll at *K* standing thirty feet above the present level of the stream, is capped by a thin veneer of Pleistocene gravels, while at the same elevation, along the sides of the marble valley of stream *H*, are benches in the marble and sometimes even slight cuts in the gneiss. Moreover, the elevation of these gravels and terraces coincides with the better-defined and more-widely distributed terrace found along the North Branch of the Patapsco. It is, therefore, probable that in Pleistocene time the stream valleys stood near he three hundred-foot contour within the territory included in the figure. At that time the heavily loaded streams brought down quantities of sand and gravels, some of which was deposited on the triangular area about *K*. Over the flood-plain thus formed the streams *G* and *H* entered the Patapsco by some common channel perhaps between the points *1* and *2*. While building this flood-plain and the level expansion of the three confluent valleys the combined forces of the streams had reduced the marble, the gneiss and the quartzite to an approximately even surface, so that at the close of the gravel-depositing period the three varieties of rocks were buried beneath the gravels and sands of the streams.

When the elevation and tilting occurred, which closed the Pleistocene deposition and revivified the overloaded and sluggish streams, *H* and *G* were incised below the flood-plain while they held a position vertically above that which they now occupy, except that *G* instead of entering the Patapsco at *1* turned eastward and joined *H* by the dotted course, *a*, and thence flowed with the latter stream to *2*. The streams cut rapidly through the old flood-plain which served to guide them for a time in their down-cutting. When the foundation of marble and quartzite was reached the deepening of the channels went forward more slowly but continued until they also were reduced to a grade about ten feet above the present channel. When this position had been reached vertical corrasion seems to have ceased for a while and the streams gave more attention to the widening of their valleys, as recorded in the broad lower portion of the valley.

In spite of the retarding influence of the quartzite, *Q*, on the downward-cutting of *H* and the opportunity which was thus given for a stream to start on the marble at *1* and work back to the elbow of *G* just above *a*, it would seem that *G* persisted in its course at *a* almost up to the time when *H* began to broaden its valley, because the floor of the notch at *a* stands at almost as low a level as does the floor of the valley about *H*. While this deepening of *H* and *G* was being accomplished a small stream at *1* was slowly working away the gravels of the Pleistocene flood-plain and the marble flooring beneath them, gradually extending its head back towards *G*. The rate at which it could develop and deepen its course was not as rapid at first as was that of *G* and *H*, because these two streams were already established and of great volume, while *1* was small and had heavy loads of gravels to remove. Both the large and the small streams flow into the same master stream, the Patapsco, whose large volume and great power enabled it to maintain its channel at a very low slope, so that there was no essential advantage, due to differences in the relative height of local base level, possessed by the stream which emptied into the river lower down. Thus the controlling factor in the rate of development of the two streams came to be a lithologic one, and the speed of down-cutting was determined by the relative resistances of the marble and the quartzite. In this respect the small stream starting at *1* had an advantage over *H* — *G*, since the former stream was located on the easily degraded marble , while the latter stream had to reduce both gneiss and quartzite before the marble could be brought to as low a level as the channel of the Patapsco.

With the advantage of being located on the marble from mouth to source *1* was able to work back and cut down so rapidly that it tapped the channel of *G* before *G* and *H* combined could quite reduce the resistant bands across their common mouth. Thus *G* was diverted from its course at *a* and led out by an easier path, while its old channel remained as a dry pathway and a low wind gap behind the knob *K*. A second uplift of lesser degree caused both the streams to trench the valley-floors which they formed after the first post-Columbia tilt, so that at present *H* is cutting a steep, rough gorge, now ten feet deep, through the quartzite and gneiss, while *G*, on its marble floor, has rapidly widened the new trench it cut until there are very slight traces of the old valley level left along its course.

MAIN STEM OF PATAPSCO.—From the confluence of the North and the South Branches to the head of the estuary of the Patapsco, the river occupies a well-marked gorge, which is sunk three or four hundred feet below the general level of the plateau. The steep sides, narrow flood-plain and rocky channel of this portion of the stream's path are well illustrated by the accompanying views, Plate X, which show the gorge in the vicinity of Ilchester and also at the mouth of Brice's Run. The features above enumerated continue without material change to the bridge at Relay, where they give place to the corresponding features developed by the stream on the less resistant sediments of the Coastal Plain. Throughout the Piedmont stretch the channel is characterized by numerous low rapids, particularly between Ellicott City and Relay, where the channel is frequently crossed by pegmatite dikes, of greater or lesser width, whose superior resistances, when contrasted with the foliated gneiss, etc., cause them to stand out as low sills across the channel. Between the sharper pitches of the channel often come stretches of rapidly flowing but unruffled waters, whose smooth surface reflects the luxuriant vegetation of the banks and adds greatly to the beauty of the stream. These quiet stretches grow longer and more frequent in the gorge above Hollofields and there accompany a slight decrease in the grade of the channel. Just at Relay the gorge widens suddenly and rapidly like the flaring mouth of a trumpet, sending the stream out into the broader valley which it has carved on the Coastal Plain. Here the stream ends its troubled course and occupies a broad, level-floored valley, bounded by lower and more gently sloping hills with terraced slopes.

There are very few examples of *terraces* along the rock-walled gorge of the main stream. Where the river crosses a T-shaped marble band at Alberton is the best and, perhaps, the only occurrence of a terrace which this portion of the Patapsco valley can show. A few hundred yards above the village the gorge suddenly broadens to a width of a quarter of a mile between its higher banks. At the same time the channel suffers a slight change in its position, so that the stream running against its south bank is there bounded by steep slopes of the gneiss rising one hundred and fifty to two hundred feet above it, while on the north it is seen to lie not more than twenty-five or thirty feet below a gravel-strewn bench, whose former even surface is now somewhat dissected by the numerous gullies and small waterways which are eating into it. This bench completely occupies the widened gorge except for the narrow trench whose floor is formed by the present channel and flood-plain. The overlying gravels are thinly strewn over it and mixed with the rich soil produced by the decomposing limestone. The pebbles are not of large size, as a rule, and usually consist of sub-angular or partly rounded fragments of vein quartz. At the down-stream corner of this terrace a slight eminence rising from it suggests a second and higher level.

The other terraces along the lower course of the Patapsco are found only after the river has left the narrow gorge and has entered the broader valley by which it crosses the edge of the Coastal Plain. Below Relay the river emerges into a broad amphitheater-like space which is bounded by low hills of the Potomac formation and the Pleistocene. The stream loses its troubled features and becomes a gently flowing current which swings in broad curves over an alluvium and gravel-covered flood-plain. The present channel and flood-plain is immediately overlooked by two terraces built of Pleistocene gravels and sands. The lower terrace has an elevation above stream channel of about fifteen feet, and is perhaps a quarter of a mile wide where best developed, *e. g.* in the vicinity of Elk Ridge Landing. The broader and more strongly marked terrace stands about forty feet above the present channel and attains a width of half a mile just below the Baltimore and Potomac Railroad.

Both these terraces may be traced from their beginning at Relay down to the shores of the harbor where they form topographic features for a short distance along the water-front. The higher terrace may also be traced for some distance up the valleys of Deep Run and the other small streams which join the Patapsco between Relay and Elk Ridge.

The type of the *tributaries* which flow into the lower course of the Patapsco is represented by Brice Run. This is a stream about five miles in length which flows southward from Randallstown and the Liberty Turnpike to join the Patapsco about half a mile above Alberton.

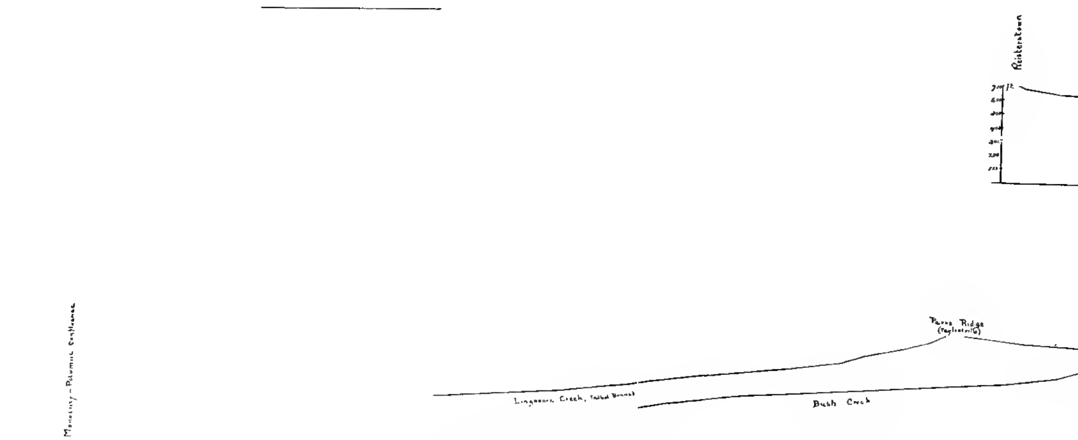
# PROFILES

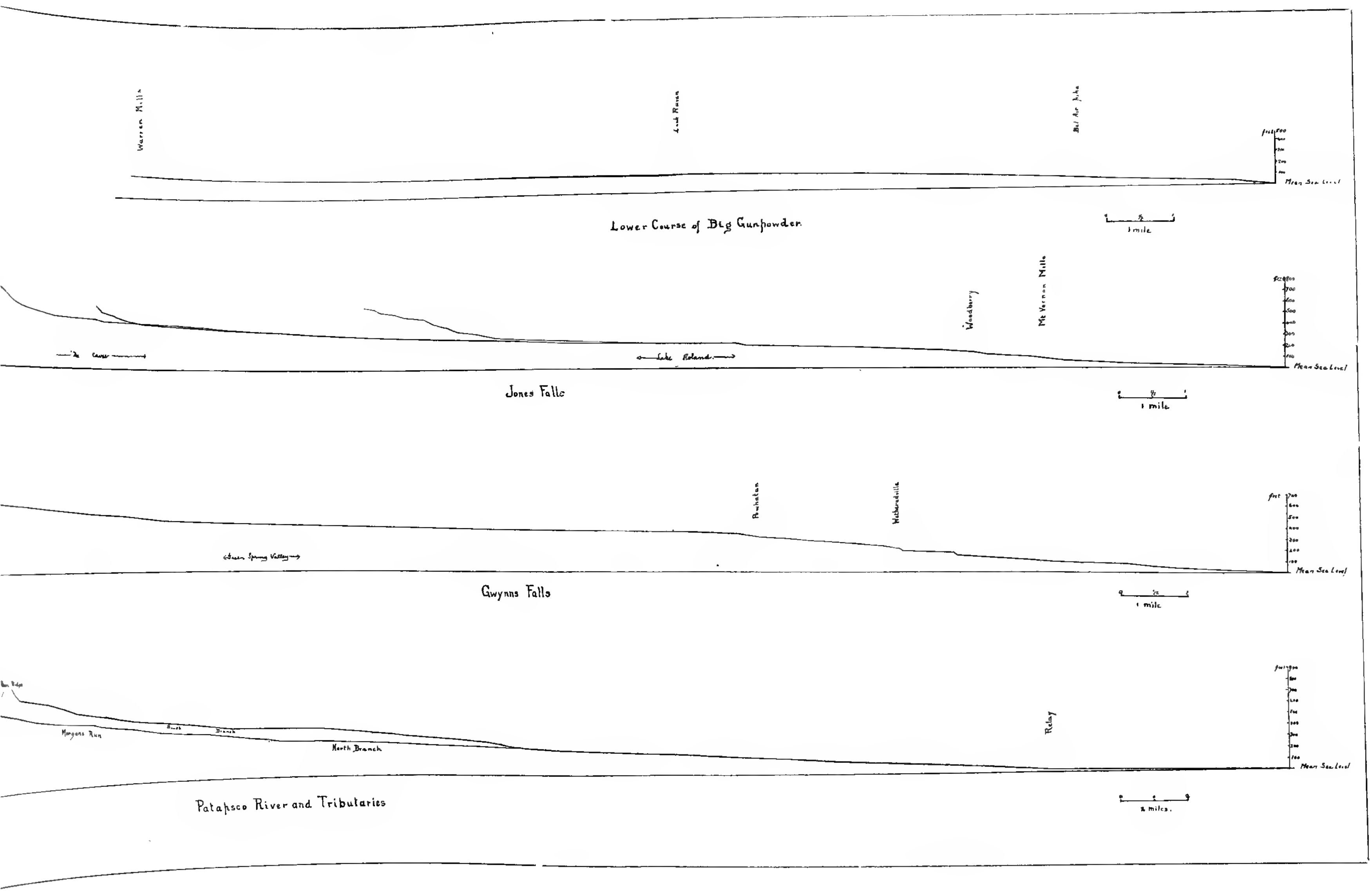
OF THE

# DRAINAGE LINES

OF THE

# EASTERN PIEDMONT PLATEAU.




Warren Mills
Bel Air Pike
Mean Sea Level
Lower Course of Big Gunpowder
1 mile
Woodberry
Mt Vernon Mills
Lake Roland
Mean Sea Level
Jones Falls
1 mile
Powhatan
Woodlawn
Mean Sea Level
Gwynns Falls
1 mile
Morgans Run
North Branch
Relay
Mean Sea Level
Patapsco River and Tributaries
2 miles

The fan-shaped area which is drained by this stream is characterized by an intricately developed drainage scheme whose broad, shallow valleys are bounded by gently sloping hills and floored by medium-sized flood-plains. The valley increases gradually in depth until about a mile from its mouth, when it begins to deepen and narrow rapidly. The stream channel itself in this lower gorge is filled with fragments from the sides of the valley and is comparatively steep, averaging forty-five feet to the mile. There is a narrow flood-plain even in this portion of the course, but its deposits of loam and alluvium are very thin, and it is largely formed of angular fragments of the gneiss, as is the channel.

The broad, open heads of the valleys, combined with the deep, narrow lower courses, are clear indications that relatively recent uplift has taken place along the zone covered by streams thus characterized. The Patapsco has since this uplift been able to cut its channel down almost to grade again, and this in a comparatively short time, because of its relatively greater volume. The side-streams having less volume and consequently less power have not been able to work as rapidly as the large stream, so that their upper courses still remain unaffected by the uplift, while their lower courses show the trenching which resulted from the change in level.

Channel Profile.—The accompanying drawing, Plate XIX, shows the vertical elevation above mean tide of the Patapsco, of its two branches and of the streams which head against them on the western slope of the divide of Parr's Ridge. The drawing includes the whole of the South Branch, the course of the main stream, and a part of the North Branch with its main tributary, Morgan's Run. As the data for completing the grades of Linganore Creek and Bush Creek were lacking they were carried only to the Monocacy.

The drawing shows that the Patapsco and its branches agree in general with the other streams of the eastern Piedmont district. The channel grade is on the whole very mild as compared with that of the western Piedmont streams. The South Branch, which is of less volume than the North Branch, is shown to have the steeper grade of the two. This is in accord with the general law that, other things being equal, the stream having the largest volume of water will reduce its channel to the lowest grade. In comparing the grades of these two streams it is well, however, to bear in mind that the North Branch has a considerable portion of its lower course arranged parallel with the strike of the foliation of the gneiss. The relation of volume to grade is brought out very clearly on comparing the grade of the Patapsco with those of the smaller Piedmont streams. Streams like Jones' Falls and Gwynn's Falls show a decided convexity upwards along that portion of their grades which just precedes their passage out into the Coastal Plain province. This feature is by no means so pronounced in the profile of the Patapsco, although the vertical exaggeration of the latter is twice as great as that of the two former streams. The milder grade of the Patapsco is due to the fact that with its larger volume it has been able to reduce its channel to a much lower level and a smoother course than it was possible for the smaller streams to do in the same length of time. That a perfectly graded course has not been attained, as yet, even by the large streams, is shown by the low falls which still characterize their channels and by the slight upward convexity of the profile.

## GENERAL CHARACTERISTICS OF THE PIEDMONT STREAMS.

### *Stream Patterns.*

The general system of division and subdivision followed by the streams of the Piedmont Plateau has been likened to the manner in which the trunk of a tree divides and subdivides. From this resemblance the system is known as *dendritic*. In the particular case of the streams which have been considered in the preceding sections the general alignment of the main streams, or the trunks of the trees, is southeastward towards Chesapeake Bay. The streams flowing into the Monocacy follow a general westward direction. Since the drainage of any district normally tends, from the very first, to arrange itself along lines determined by the distribution of the rocks encountered, it is evident that the history of many of the streams of the Piedmont are somewhat abnormal, as they very rarely follow courses which are in accord with the structure. The most striking cases of divergence are furnished by the larger streams, such as the Big Gunpowder, the

Patapsco and the Monocacy. Equally significant examples, however, are found among some of the tributary and smaller streams. For example, the dendritic headwaters of Western Run are strikingly out of adjustment with the long, narrow bands of gneiss and marble lying across their paths. The whole course of Deer Creek is at variance with the relative resistances of the quartzite, the gneiss and the serpentine bands across which it flows. About the small head-streams of the Patuxent there are ample opportunities for adjustment in the presence of several bands of soluble marble, but only the very smallest rivulets have assumed subsequent courses.

The small streams at the very head of the West Branch of the Gunpowder, the corresponding streams of the North Branch of the Patapsco, Little Deer Creek, and several small streams on various marble areas include most of the noteworthy instances. There is, however, a rather numerous class of streams, like Jones' Falls, Western Run, and the westward flowing tributaries of the Monocacy, which show a partial adjustment to the rocks of their drainage basins.

### *Valleys.*

From the facts just given it follows that the valleys of the streams naturally fall into two main groups, viz.: (1) valleys which are entirely at variance with the general structure and, (2) valleys which conform more or less completely to the variations in the rocks. The two sets of valleys have rather different characters in certain portions of their courses.

All those streams whose headwaters do not lie in subsequent valleys are characterized in this portion of their course by comparatively broad, open and shallow basins lying comparatively close to, if not actually on, the upland surface. As these streams descend their valley-walls gradually close in, their side-slopes steepen and within eight or nine miles of their mouth they enter narrow, steep-sided gorges which continue until the streams reach sea-level.

Those valleys which are determined in their location by the presence of yielding rocks, and therefore belong to the class of subsequent valleys, may be again subdivided into two classes. One class includes the valleys made by the streams which now occupy them. These are represented by Little Deer Creek, and Broad Creek above Pylesville, and Long Green Valley. They are peculiarly distinguished by the very commonplace fact that the streams traverse them from end to end, longitudinally. The second class consists of those valleys which apparently were not fashioned by the streams now traversing them. These are peculiarly distinguished by containing the remnants of an earlier filling and by the fact that the streams draining them usually *cross* them transversely. The class is represented almost solely by the irregularly outlined depression embracing Green Spring, Dulaney's, Mine Bank Run and Cockeysville valleys.

### *Channel Profiles.*

Comparative studies of the channel profiles show that the Piedmont streams possess several peculiarities. In the first place, their channels do not possess the normal profile curve throughout as this is typically represented in Fig. 3; secondly, the divergences from the normal profile occur altogether along the lower courses of the streams; and, finally, the profiles of the westward flowing streams are found to be both steeper and more nearly normal than those flowing eastward.

The fact that these stream profiles do not show the normal channel curve throughout their extent is a clear indication that there has been at least one interruption in the uniform development of the streams, and this interruption has been of the nature of a general uplift, or series of uplifts, since only that could cause the lower courses of the numerous eastern streams to show the convex-upward profile which is characteristic of immature streams, while the upper courses of the streams retain the mature concave profiles developed before the uplift. Moreover, there is an obvious and close connection between the steep, narrow gorges, which belong to the lower courses of all the Chesapeake streams of the Piedmont, and this convexity of the lower portions of their channel-grades.

Even more interesting, however, is the comparison of the profiles of the streams on either side of Parr's Ridge. It has already been remarked that the Monocacy tributaries have much steeper grades just at the divides. They also are of much milder grade in the middle and lower sections of their courses, and reach a lower elevation more rapidly than their eastern opponents. This marked contrast in the grades of the two sets of streams is evidently due to a common cause. The Monocacy flows, throughout most of its course, either on limestone or on the yielding Newark formation, while the eastern Piedmont streams have by no means such an easy path. Thus the Monocacy and its tributaries have always kept their lower courses close to the mild, low grade of the powerful Potomac, and have been able to push back their headwaters vigorously against those of the other streams.

These present conditions suggest a new explanation for the formation of Parr's Ridge involving the relations between the rocks of the eastern and the western Piedmont during the production of the Schooley peneplain. Then, as now, the Potomac river was the great master stream of the whole Province and was able to maintain a comparatively low grade. The present distribution of the Newark and of its remnants, taken in connection with various discordant drainage features among the eastern tributaries of the Monocacy, indicate that the Newark formation formerly extended farther east towards what is now Parr's Ridge.

Granting that the Newark formation had an even greater extent in Jurassic time than it has to-day, and understanding from present profiles what advantages the Potomac tributaries possess, it must be conceded that the Monocacy river, or a closely similar stream, occupied a subsequent valley on the Newark. Such being the case, the eastern tributaries of that stream must have had advantages over the eastern Piedmont streams in those times just as they do to-day. It therefore seems probable that Parr's Ridge remained as a low divide during the formation of the Schooley peneplain.

## HISTORY OF THE PIEDMONT STREAMS.

### *Origin.*

Any account of the origin of the streams of the Piedmont Plateau must, in order to be satisfactory, explain the several seemingly anomalous characteristics which they present. The chief of these anomalies is the fact that although the streams are well developed yet they show an almost total disregard for the underlying rock structure.

Lesser peculiarities are the minor discordances and adjustments, and the peculiar location of a number of streams against the southern or southeastern limit of their valleys.

The discordance between the streams and the structure of the Plateau is so wide-spread that some wide-spread cause is necessarily required to explain it. Such wide-spread discordances can only result from the streams cutting down through a broad blanket of some sort which hid, at the time of the origin of the streams or early in their history, the structure and topography later discovered. Thus the broad loess deposits of China and of the central United States serve as such covers through which the streams of to-day have already cut or are cutting their way down to the underlying rocks. The broad sheets of glacial till of the north, or the less extensive lacustrine clays of Lake Agassiz or Lake Bonneville, serve the same purpose for their respective regions. The deep mantle of disintegrated material which forms the soil and subsoil in more southern districts might also serve as an agent of superposition. It is of a comparatively uniform degree of resistance, thus resembling the glacial and lacustrine deposits and producing similar drainage patterns for the streams which originate on it.

In the partially removed cover of Coastal Plain sediments there is ample evidence of a past ability to produce such a phenomenon, provided there is enough evidence to warrant the conclusion that the Coastal Plain has thus served the drainage of the Plateau. To prove this it must be shown—

1. That the Coastal Plain has covered those portions of the Plateau which now show discordant drainage.

2. That the superimposed drainage, if it came from the Coastal Plain, ought to have its general direction in accord with the drainage lines of the latter and its general pattern of the same type.

There is some evidence favoring the first condition in the occurrence of several outlying remnants of the Coastal Plain deposits. To this may be added the just conclusions, based on considerations of the lithological characters of these sediments that they once extended farther west, and that they do not now occupy exactly their old shore-lines. Both of the features required by the second condition have already been shown to be characteristic of the major portion of the drainage under consideration. It therefore seems a true conclusion that the streams of the eastern portion of the Piedmont Plateau originally took their courses on the surface of the Coastal Plain; that the streams cut down through this cover and laid bare the old surface of the Piedmont region, at the same time establishing themselves thereon in courses out of harmony with the varying lithologic character of the region.

### *Minor Discordances.*

The Pleistocene subsidence of the lower courses of the streams permitted the contemporaneous accumulation of broad, gravelly and sandy flood-plains, occupying the valleys of Western Run, Dulaney's Creek, Mine Bank Run and Beaver Dam Creek, as well as Green Spring Valley. It is a well-understood fact that when a river has reached the flood-plain building stage, it is in a state of delicate balance, so that a very slight disturbing element can cause the stream to shift its course very decidedly. With this in mind, the unsymmetrical location of the streams in the valleys mentioned, and the sometimes discordant positions which they have taken, may be explained as follows. The Pleistocene period of flood-plain building was brought to an end by a general elevation which was of the nature of a tilting towards the southeast. This tilt caused all the east-and-west and northeast-southwest streams to slide over their flood-plains southward or southeastward. Thus Dulaney's Creek and its companion became located upon the ledge of gneiss which they had reduced; the streams in the northeastern portion of Mine Bank Run valley shifted over upon the pegmatite dike; and Western Run, Piney Run and Jones' Falls took their present positions along the southern limits of their valleys. The elevation which accompanied the tilt revived the streams and caused them to trench their channels below the Pleistocene flood-plains, thus initiating the period of active erosion which caused the convexity of all the eastern stream profiles.

### *Recent Changes.*

Since the Pleistocene deposition and post-Pleistocene elevation, further adjustments have probably gone on, the streams have incised themselves more deeply in the positions which they inherited from the tilted flood-plains, and there is a general tendency to reduce the stream-grades as rapidly as possible.

## CONCLUSION.

The results of the study of the Piedmont Plateau drainage may be summarized as follows:

1. The streams of the eastern division of the Piedmont Plateau have been superimposed from the formerly more extensive Coastal Plain cover.

2. The date of this superimposition is probably post-Lafayette, although there are some facts that point to its initiation in post-Potomac time.

3. Secondary superimposition from Pleistocene flood-plain deposits in *subsequent valleys* show that recent elevation has been accompanied by a tilting toward the southeast.

4. The westward extension of the Coastal Plain, as evidenced by the discordant drainage which it produced and by sedimentary records, cannot be traced with certainty west of Parr's Ridge.

5. The minor cases of discordance which occur in the drainage of the Monocacy are the result of superimposition from the Newark formation.

6. Parr's Ridge has been, as it is now, the divide between Monocacy and Chesapeake Bay streams since late Jura-Trias times; it is being gradually shifted eastward because of the greater activity of the Monocacy drainage; and it represents, not a part of the plain-surface, but a low, minor divide on the Schooley peneplain.

# VITA.

Cleveland Abbe, Jr., was born in Washington, D. C., March 25, 1872. He is the son of Cleveland Abbe, of New York City, and Frances M. Neal, of Cincinnati, Ohio. His early education was received at home and later from the public schools of Washington. After graduating from the High School of that city in 1890, he entered Harvard College in September of the same year, becoming a member of the Class of 1894. While pursuing a general course, in college, he became particularly interested in the study of Geology and Physical Geography under Professors N. S. Shaler and W. M. Davis. On graduating in June, 1894, he returned to spend another year under Prof. Davis and others, devoting his time to Physical Geography, Glacial Geology and Pedagogy. During this year, 1894-95, he held a University Scholarship.

In the fall of 1895 the candidate came to Baltimore and entered the Geological Department of Johns Hopkins University as a graduate student. Here he pursued a special course in Geology for three years, accompanied by three summers of active field-work in the employ of the Maryland Geological Survey. In 1896 he was awarded one of the University Scholarships in Johns Hopkins University, and in 1897 was appointed Fellow in Geology in the same university. The degree of Master of Arts was conferred upon him in 1896 by Harvard University, as the result of the work done there in 1894-95 and of special work done about Baltimore in 1896.

In conclusion, the candidate wishes to express his regard for and obligations to Prof. Wm. B. Clark of this University, whose continued kindly encouragement has brought him through many difficult places and without whose very material assistance the field-work required for the present study would not have been so thoroughly carried out. To Prof. E. B. Mathews of Johns Hopkins University, Prof. R. E. Dodge of Teachers' College, Columbia University, and to many friends in the U. S. Geological Survey are due thanks for helpful comments, suggestions and discussion. From Prof. W. M. Davis of Harvard University has come the initial and enduring enthusiasm for the work presented.